(12)

February 1993

UG-0027

USER'S GUIDE

SEISMIC HAZARD ANALYSIS

by

J. M. Ferritto

NAVAL CIVIL ENGINEERING LABORATORY
Port Hueneme, CA 93043-4328

Sponsored by
Office of Naval Technology

REPORT DOCUMENTATION PAGE	*Form Approved OMB No. 0704-018*

Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project (0704-0188), Washington, DC 20503.

1. AGENCY USE ONLY *(Leave blank)*	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	February 1993	Final: Oct 1992 through Feb 1993

4. TITLE AND SUBTITLE	5. FUNDING NUMBERS
USER'S GUIDE - SEISMIC HAZARD ANALYSIS	PR - RM33F60-001-0106 WU - DN387338
6. AUTHOR(S) J.M. Ferritto	
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESSE(S) Naval Civil Engineering Laboratory 560 Laboratory Drive Port Hueneme, CA 93043-4328	8. PERFORMING ORGANIZATION REPORT NUMBER UG-0027
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESSE(S) Office of Naval Technology Arlington, VA 22217-5000	10. SPONSORING/MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION/AVAILABILITY STATEMENT	12b. DISTRIBUTION CODE
Approved for public release; distribution unlimited.	

13. ABSTRACT *(Maximum 200 words)*

An automated procedure has been developed to perform seismic analysis using available historic and geologic data. The objective of the seismicity study is to determine the probability of occurrence of ground motion at the site. Response spectra and time history techniques are presented.

14. SUBJECT TERMS	15. NUMBER OF PAGES
Earthquake, seismic, response spectra, time history, site acceleration	128
	16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
Unclassified	Unclassified	Unclassified	UL

INTRODUCTION - What is a Seismicity Study

The objective of a seismicity study is to quantify the level and characteristics of the earthquake ground motion which pose a risk to a site of interest. The seismicity study will produce a probability distribution of expected site acceleration for a given exposure period and also give an indication of the frequency content of that motion. The approach taken in this work is to use the historical epicenter data base in conjunction with geologic data where available to best estimate the earthquake recurrence of a region or fault. This recurrence relationship is used to determine the regional or fault contributions to the overall site acceleration level. This becomes the basis for definition of response spectra suitable for use in structural design and analysis. The procedure utilizes three parts to accomplish the study. The first part creates a subset of earthquakes from the general data base and plots all events within a specified region. The second part utilizes the epicenter data to perform a regional analysis determining the magnitude recurrence relationship for the region which may be adjusted for geologic data where known. Additionally the program computes the probability of acceleration at the site location and gives plots of recurrence and acceleration data. The third part analyzes individual faults. It determines fault magnitude recurrence and probability of acceleration at the site from an event on each fault specified. Geologic data may be used to augment historical epicenter date. Each part will be discussed in detail below.

GETTING STARTED

System Requirements

The Program is designed to run on standard desk top personal computers using the MS DOS operating system version 3 or higher. The following are required:

MS DOS version 3 or higher
640 k system memory
Hard disk
80287 math coprocessor

optional devices

plotter
printer

The following plotters are supported:

EPSON FX80 printer or compatible (used as plotter)
Hewlett Packard Laserjet printer or compatible
Hewlett Packard Plotters
Houston Instruments Plotters
Tecktronix 4025

Loading The Program

Place the first PROGRAM DISK in Drive A: switch to Drive A then type:

A> INSTALL <cr>

This will create a directory on the C hard disk named SEISMIC and load all of the programs into that directory. When complete, place the next disk in Drive A and type INSTALL as above to continue loading the program.

Place the first DATA DISK in Drive A: type INSTALL as above. This will create a directory named EPICENTR and load the data files. Place the remaining DATA DISKS in sequence in Drive A and type INSTALL as above to load all data.

Place the SAMPLE DATA DISK in Drive A: type INSTALL as above. This will create a directory named OUTPUT and load the data files.

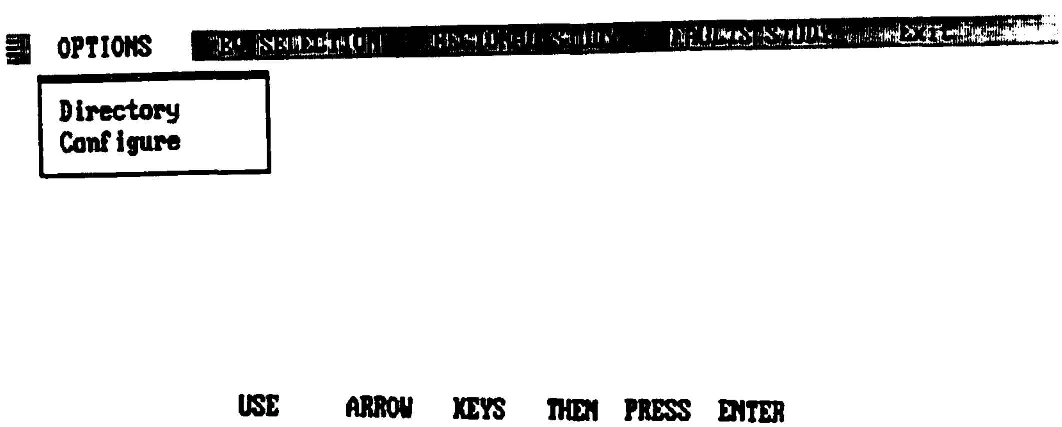
See the ADVANCED USER section to deviate from these locations for program and data.

Configuring The Program

The program supports a number of graphic output devices; the user must specify which device is being used and how it is connected. He must also tell the program where the data files are being stored. To begin the configuration switch to the program directory and start the program by typing the following:

C:
CD\SEISMIC
SEISMIC

The following screen will appear:



The program has five choices which form the opening menu: Options, Earthquake Selection, Regional Study, Fault Study, and Exit. Use the LEFT and RIGHT ARROW keys which are on the number pad keys with the 4 and 6 to move among the choices. Make sure the NUM LOCK key is off to permit the arrow keys to function. When the OPTIONS choice is selected a window opens giving two choices: Directory, and CONFIGURE. Use the down arrow key to choose the CONFIGURE choice then press ENTER (or RETURN). The following screen appears:

Enter Plotter DEVICE NUMBER see User's Manual e.g. LPT1 = 1	1
Enter Plotter MODEL NUMBER see User's Manual e.g. HP Lasejet =60	60
Enter Drive and Directory for EPICENTER files example C:\EQUAKES	F:\EQUAKES
Enter Drive and Directory for OUTPUT files example C:\OUTPUT	F:\SEISMIC

Any Changes? Y / N

The DEVICE NUMBER refers to the port to which the hard copy plotting device is connected; see Table 1 for configuration options and check the manual for the hard copy plotting device. Enter the DEVICE NUMBER then press ENTER or DOWN ARROW.

The MODEL NUMBER can be obtained from Table 2a for the devices supported by the program. Laser printers produce high quality plots rapidly and are recommended. Table 2b gives a matrix MODEL NUMBERs for various compatible printers which can be used to obtain plots. Table 3 gives the recommended configuration for specific devices. Enter the MODEL NUMBER then press ENTER or DOWN ARROW.

Type the directory name where the epicenter data files are located. If you used the INSTALL routine to accept the default directory creation then type:

C:\EPICENTR

Note the back-slash (\) key and the spelling of EPICENTR, 8 letters without the E. If you chose to locate the programs else where enter the following:

Drive letter:\Directory

example D:\EPIC

Table 1. Device Number

Device Number	Output Device				
	Parallel Port				
0	PRN: (PRN: is equivalent to LPT1:)				
1	LPT1:				
2	LPT2:				
3	LPT3:				
	-console-				
99	CON: Console				
	-serial ports-				
	device	baud rate	parity	#data bits	#stop bits
300	COM1:	300	N	8	1
301	COM1:	300	O	7	1
302	COM1:	300	E	7	1
1200	COM1:	1200	N	8	1
1201	COM1:	1200	O	7	1
1202	COM1:	1200	E	7	1
4800	COM1:	4800	N	8	1
4801	COM1:	4800	O	7	1
4802	COM1:	4800	E	7	1
9600	COM1:	9600	N	8	1
9601	COM1:	9600	O	7	1
9602	COM1:	9600	E	7	1

parity: N=None
E=Even
O=Odd

COM2:=Add 50 to value for COM1:

Table 2a. Model Number

Model Number	Printer-Plotter-Screen Device Identification
0	Epson FX-80 Printer, single density.
1	Epson FX-80 Printer, double density.
2	Epson FX-80 Printer, double speed, dual density.
3	Epson FX-80 Printer, quad density
4	Epson FX-80 Printer, CRT Graphics I.
5	Epson FX-80 Printer, plotter graphics.
6	Epson FX-80 Printer, CRT Graphics II.
10	Epson FX-100 Printer, single density.
11	Epson FX-100 Printer, double density.
12	Epson FX-100, double speed, dual density.
13	Epson FX-100 Printer, quad density.
14	Epson FX-100 Printer, CRT Graphics I.
15	Epson FX-100 Printer, plotter graphics.
16	Epson FX-100 Printer, CRT Graphics II.
20	HP 7470A Graphics Plotter.
30	HP 7475A Graphics Plotter.
40	Epson LQ-1500 Printer, single density.
41	Epson LQ-1500 Printer, double density.
42	Epson LQ-1500, double speed, dual density.
43	Epson LQ-1500 Printer, quad density.
51	Houston Instrument DMP-51 MP or DMP-52 MP Plotter, 0.001" step size.
52	Houston Instrument DMP-51 MP or DMP-52 MP Plotter, .005" step size.
60	HP 2686A LaserJet Printer or LaserJet PLUS printer, using A size paper (8.5" x 11") (216 mm x 280 mm). Drawing resolution: 75 dots per inch.
61	HP 2686A LaserJet Printer, using B5 size paper (7.2" x 10.1") (182 mm x 257 mm). Drawing resolution: 75 dots per inch.
62	HP 2686A LaserJet Printer, using A size paper (8.5" x 11") (216 mm x 280 mm). Drawing resolution: 150 dots per inch.
63	HP 2686A LaserJet Printer, using B5 size paper (7.2" x 10.1") (182 mm x 257 mm). Drawing resolution: 150 dots per inch.
64	HP 2686A LaserJet Printer, using A size paper (8.5" x 11") (216 mm x 280 mm). Drawing resolution: 300 dots per inch.
65	HP 2686A LaserJet Printer, using B5 size paper (7.2" x 10.1") (182 mm x 257 mm). Drawing resolution: 300 dots per inch.

continued

Table 2a. (continued)

80	HP 7580B, HP 7585B, or HP 7586B Drafting Plotter using size A/A4 to D/A1 paper. HP 7550A Graphics Plotter using size A/A4 to B/A3 paper. HP 7440A ColorPro plotter using size US/A4 paper.
85	HP 7585B or HP 7586B Drafting Plotter using size E/A0 paper.
90	Tektronix 4025.
99	IBM color graphics monitor (CRT).

Table 2b. Dot Matrix Printer Usage by Model

Printer	Model													
	0	1	2	3	4	5	6	10	11	12	13	14	15	16
Epson FX-80	*	*	*	*	*	*	*							
Epson MX-80	*	*	*	*										
IBM Printer	*	*	*	*										
Centronics GLP	*	*	*	*										
Okidata 92	*	*	*	*										
Epson RX-80	*	*	*	*	*		*							
Epson FX-100								*	*	*	*	*	*	*
Epson MX-100								*	*	*	*			
Okidata 93								*	*	*	*			

* = The printer can use this model number.

Table 3. Recommended Configuration

Output device	Device	Model
Epson FX-80	0	5
Epson MX-80	0	1
IBM Printer	0	1
Centronics GLP	0	1
Okidata 92	0	1
Epson RX-80	0	1
Epson FX-100	0	15
Epson MX-100	0	11
LQ-1500	0	41
Okidata 93	0	11
HI DMP-51	9600/9650	51
HI DMP-52	9600/9650	51
HP 7440A	9600/9650	80
HP 7470A	9600/9650	20
HP 7475A	9600/9650	30
HP 7550A	9600/9650	80
HP 7580B	9600/9650	80
HP 7585B	9600/9650	80/85
HP 7586B	9600/9650	80/85
HP 2686A	9600/9650	60/61
Tektronix 4025	4800/4850	90
IBM color graphics monitor	.99	99

No spaces are allowed in the name. For further information see your DOS manual on sub-directory creation and naming. Press ENTER or DOWN ARROW to advance to the next item.

Type the directory name where the output files are located. If you INSTALLed the SAMPLE DATA you created a directory called:

C:\OUTPUT

If you did not then a directory has not been created. Select and type a name for the output file location such as:

C:\OUTPUT

Remember this name; we will use it again. Press ENTER

Upon completion, you are asked if you wish to make changes. If everything is correct type N for no or else Y for yes and repeat the data entry. Use DOWN ARROW keys to skip over acceptable answers and change only what is in error.

If you did not use the INSTALL for SAMPLE DATA do the following. When N for NO CHANGES is pressed the program returns to the OPTIONS WINDOW. Use the RIGHT ARROW key to EXIT. When out of the program create the OUTPUT LOCATION directory if one does not exist. Type the following:

```
CD\
MD\OUTPUT
CD\SEISMIC
SEISMIC
```

The opening screen will reappear as shown above. This time press ENTER to accept the DIRECTORY choice. A screen like the following will appear showing the earthquake epicenter files on disk.

DIRECTORY F:\EPIC*.EPC

11 file(s) found

E2.EPC	E8.EPC
E1.EPC	E9.EPC
E3.EPC	E10.EPC
E4.EPC	E11.EPC
E5.EPC	
E6.EPC	
E7.EPC	

Filename : E2.EPC

Use cursor keys to select file then press <ENTER>

Press ENTER to continue and a directory of the files in the output location directory will appear:

DIRECTORY F:\SDATA*.*

16 file(s) found

ONE.PLT	TWO.PL	TEST.3PT
TWO.PLT	TWO.OU	RESPONSE.PLT
THREE.PLT	TEST.3OT	
ONE.OUT	TEST.1OT	
TWO.OUT	TEST.1PT	
THREE.OUT	TEST.EQS	
EQUAKES	ONE.PL	

Filename : ONE.PLT

Use cursor keys to select file then press <ENTER>

Press ENTER to return to the OPTIONS window menu. We are now ready to begin a problem.

EARTHQUAKE SELECTION

The epicenter data base has been prepared from the National Oceanic and Atmospheric Administration's data base. Each file covers a specified region and contains date, latitude, longitude and magnitude data. This section is used to create a subset of earthquakes for a specific region from the main set of earthquake files. The program searches a rectangle specified by maximum and minimum latitudes and longitudes to find all events within the box above the specified magnitude. To become familiar with the program, the user may advance to the EQ SELECTION. The following screen appears:

OPTIONS EQ SELECTION REGIONAL STUDY FAULTS STUDY Exit

Specify Area Revise Data Begin Analysis
View Results Print Results Plot Results Save Results

USE ARROW KEYS THEN PRESS ENTER

Use the DOWN ARROW key and then choose REVISE DATA to see the example problem. Press RETURN to accept each value unchanged. Then select VIEW RESULTS from the EQ SELECTION window to see the output file on screen. Selecting PRINT RESULTS or PLOT RESULTS will print or plot the sample problem.

Specify Data

This choice permits data entry for a new problem. Selecting this choice will overwrite previous data examples unless they were saved to a named file. You will overwrite the sample data but it can be copied from the original disk again if needed. The following screen will appear:

Enter Maximum Longitiude (Degrees) example 120.0	121
Enter Minimum Longitude (Degrees) example 112.0	113
Enter Maximum Latitude (Degrees) example 40.0	41
Enter Minimum Latitude (Degrees) example 34.0	37
Enter Site Longitude (Degrees) example 115.0	115
Enter Site Latitude (Degrees) example 38.0	38
Enter Minimum Magnitude Cutoff example 3.0	3.0

Any Changes? Y / N

Enter the longitude and latitude for a rectangle bounding the problem and the site longitude and latitude. The study area must be large enough to include distant events which can influence the site. Geologic data should be consulted to look for boundaries of tectonic provinces. The site should be near the center of the study region unless otherwise required by a tectonic boundary. The region will form the boundary for selecting events to be used in the study and are relevant to establishing the site seismic potential. For regional studies consideration should be given to selecting an area large enough to establish the regional tectonic setting. Enter the MINIMUM MAGNITUDE CUTOFF value, typically 3.0. Events below this level may not have been recorded and their absence distorts the relationship for recurrence.

The program computes the acceleration at the site location from each epicenter location where a magnitude is specified in the subset of earthquakes. This computation uses an acceleration distance attenuation equation. The following attenuation relationships for acceleration are included:

1. McGuire (1978)
2. Trifunac and Brady (1975)
3. Campbell (West) (1982)
4. Campbell (East) (1982)
5. Donovan and Bornstein (1978)
6. Joyner and Boore (1981)

The user is has the option of selecting which to use. Since each equation analyzes the data differently and since there is a large uncertainty in ground motion results may differ depending upon the equation selected. The user is encouraged to read the references. The following screen is used to enter the acceleration equation choice and the hypocenter depth if needed, usually 10 miles.

1 Mc Guire

2 Trifunac and Brady

3 Campbell (Western US)

4 Campbell (Eastern US)

5 Donovan and Bornstein

6 Joyner and Boore

1

Enter depth to hypocenter (miles) 8

ENTER CHOICE FOR ACCELERATION EQUATION

Once the acceleration equation data entries are completed, the user is asked to select epicenter files to be searched . Files have been divided into regions to keep the search time to a minimum. A screen similar to the following is shown from which the user may move through the list using the ARROW KEYS, PAGEUP/DOWN KEYS and then press ENTER to select his choices. There is no limit to the number of choices.

```
Calif 114-119 31-32
Calif 114-120 32-33
Calif 114-121 33-34
Calif 114-122 34-35
Calif 114-123 35-36
Calif 114-123 36-37
Calif 114-123 37-38
Calif 114-124 38-39
Calif 114-125 39-40
Calif 114-125 40-41
Calif 114-125 41-42
```

Press ESCAPE when done. The program then shows the choices and asks for confirmation.

```
YOU HAVE SELECTED THE FOLLOWING RECORDS:

7     Calif 114-123 37-38
8     Calif 114-124 38-39
9     Calif 114-125 39-40
10    Calif 114-125 40-41
11    Calif 114-125 41-42



IS THIS CORRECT? Y/N
```

Revise Data

If the user wishes to revise a number he may choose the REVISE DATA choice and will be given the same questions as in the SPECIFY DATA section with the previous choices. Press enter or DOWN ARROW to accept the value unchanged. Overwrite the revised value completely to alter a number.

Begin Analysis

This choice begins the actual data search.

View Results

The VIEW RESULTS choice permits the user to see the output file from an analysis on the screen. It must be run after an analysis has been performed and data exists.

Print Results

PRINT RESULTS prints the output files. The output consists of a list of epicenters with the computed site acceleration for that event, and a histogram of the distribution of acceleration.

THE FOLLOWING IS AN EXAMPLE OUTPUT

MAX LONGITUDE	73.000
MIN LONGITUDE	69.000
MAX LATITUDE	44.000
MIN LATITUDE	41.000
MIN MAGNITUDE	.000
MAX MAGNITUDE	9.000
SITE LONGITUDE	72.000
SITE LATITUDE	42.000
ACCELERATION EQUATION	.000

LIST OF SITE EPICENTERS

YEAR	LATITUDE	LONGITUDE	MB	MS	MO	ML	AVM	DISTANCE	ACCEL
1976.	41.66	69.97	.00	.00	.00	3.00	3.00	106.776	.003
1979.	43.98	69.80	3.80	.00	4.00	4.10	3.97	177.364	.004
1977.	41.84	70.70	.00	.00	3.10	.00	3.10	67.614	.006
1974.	41.70	71.50	.00	.00	.00	2.50	2.50	32.976	.008
1976.	41.56	71.21	.00	.00	.00	3.50	3.50	50.660	.011

where

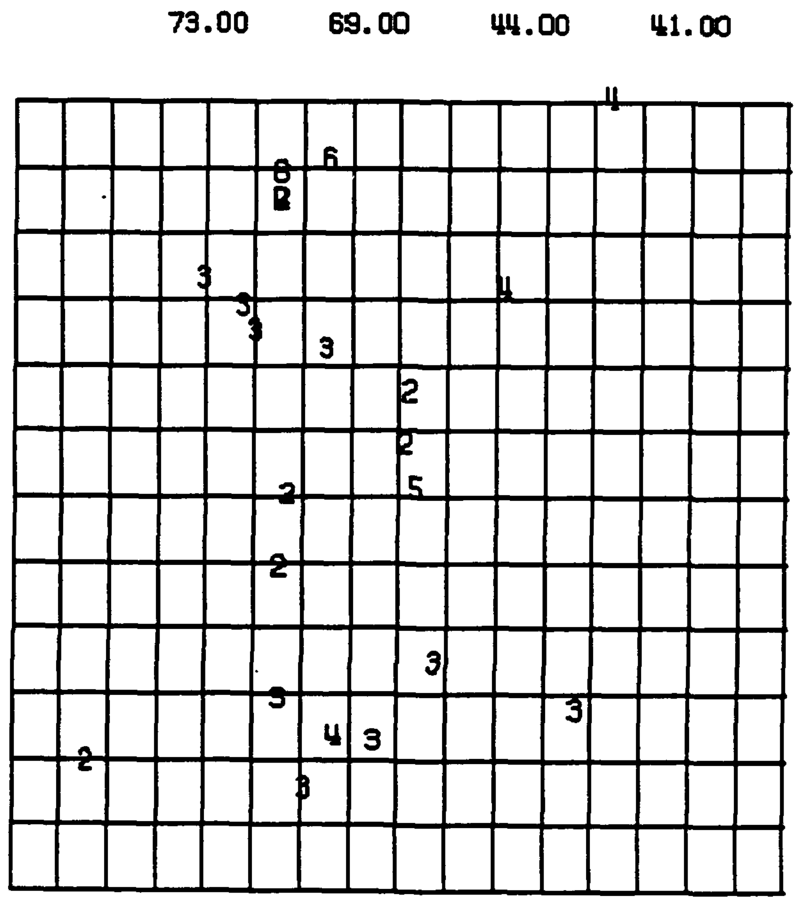
MB	Body wave magnitude
MS	Surface wave magnitude
MO	Other magnitude
ML	Local magnitude
AVM	Average magnitude
DISTANCE	Distance event to site
ACCEL	Site acceleration computed estimate, g's

Plot File

This choice creates an epicenter plot for the region. Figure 1 is an example plot.

Save Results

This choice permits the user to write the input, output and plot files to a named file of the user's choice. This prevents the files from being overwritten.



Note: numbers are approximate magnitudes

Figure 1. Epicenter plot for region.

REGIONAL STUDY

Moving the RIGHT ARROW key to REGIONAL STUDY reveals the following screen:

REGIONAL STUDY

Specify Region
Revise Data
Begin Analysis

View Results
Print Results
Plot Results
Save Results
Response Plot

USE ARROW KEYS THEN PRESS ENTER

This section is used to conduct a regional seismicity study typically for eastern sites where faulting is not known It uses the epicenter subset created previously . This section will estimate the level and characteristics of the earthquake ground motion which pose a risk to the site of interest. We will use the historical epicenter data base in conjunction with geologic data where available to best estimate the probability of site acceleration levels. This becomes the basis for definition of response spectra suitable for use in structural design and analysis.

For a regional analysis the epicenter data base is used to define the regional magnitude recurrence based on a log-linear fit of the data and the Richter A and B recurrence coefficients are determined.

$$\mathrm{Log}\ (N) = A + B\ M$$

The program allows the user to specify minimum cutoff magnitude to enhance the fit. Generally the epicenter data base is deficient on small events since events less than magnitude 3 may not be large enough to be recorded at distant seimograph stations. Thus a cutoff of 3 is usually used to insure the fit of the data is through the linear portion of the data. Figure 2 illustrates the case in which the initial data did not use a cutoff minimum magnitude. The line should be fit through the linear portion. The program may be repeated, with the user specifying the A and B coefficients based on his modification to the computed fit of the data.

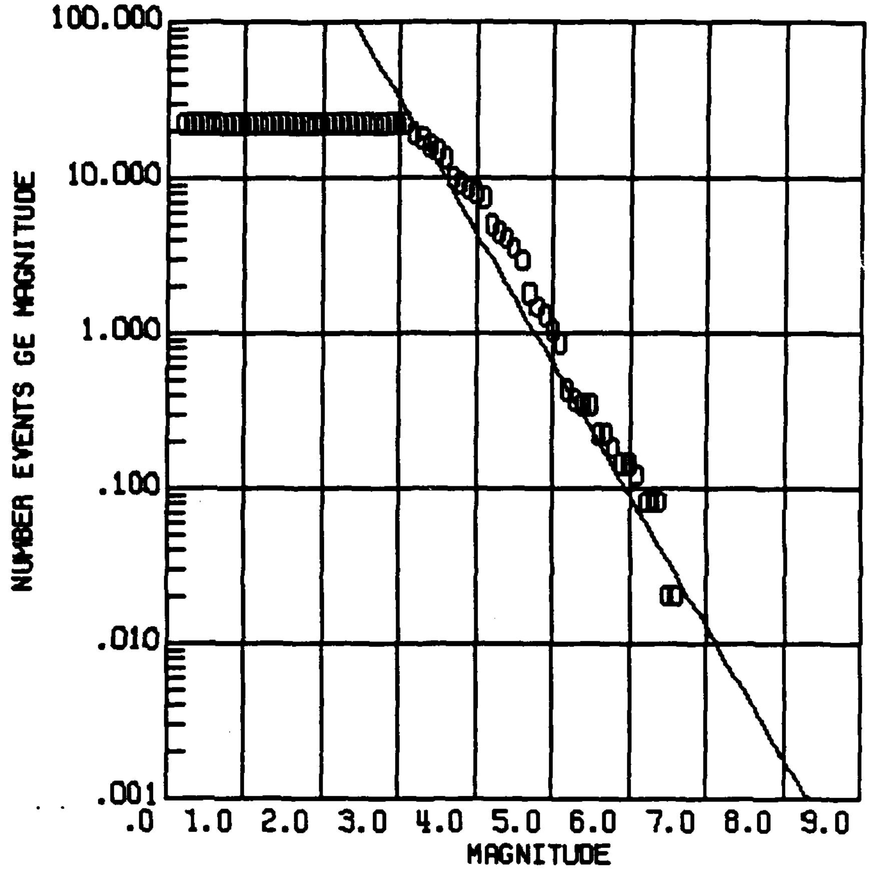


Figure 2a. Regional earthquake recuccence.

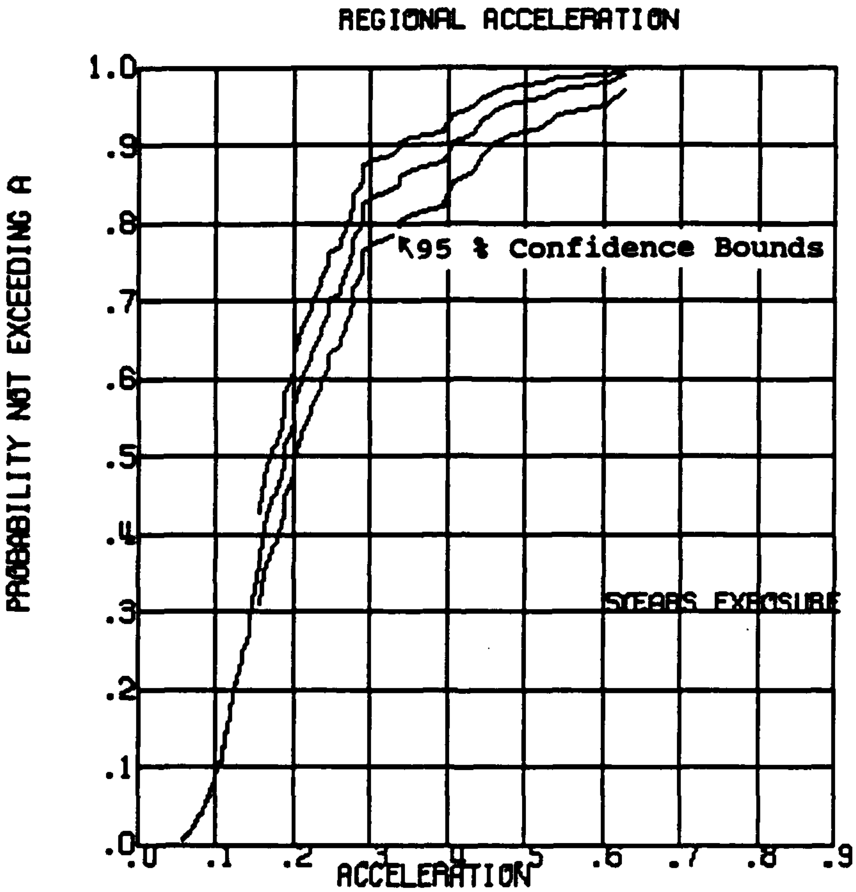


Figure 2b. Probability of acceleration at site based on regional seismicity.

Having established the magnitude recurrence relationship, a "floating" earthquake analysis is performed using a Monte Carlo simulation routine A series of events representing a 5000 year exposure are randomly, spatially assigned with magnitude shaped by the recurrence relationship. A maximum cutoff magnitude may be included to fit the tectonics of the region. A probability distribution for a specified exposure period of acceleration at the site location is computed. The simulation process is random in location and includes the error associated with the earthquake attenuation equations. A histogram of magnitude and acceleration is computed.

Use the DOWN ARROW key and then choose REVISE DATA to see the example problem. Press RETURN to accept each value unchanged. Then select VIEW RESULTS from the window to see the output file on screen. Selecting PRINT RESULTS or PLOT RESULTS will print or plot the sample problem.

Specify Region

From the REGIONAL STUDY window select SPECIFY REGION and press ENTER. The following questions will appear:

Enter Maximum Longitiude (Degrees) example 120.0	121
Enter Minimum Longitude (Degrees) example 112.0	116
Enter Maximum Latitude (Degrees) example 40.0	41
Enter Minimum Latitude (Degrees) example 34.0	36
Minimum Earthquake Magnitude Cutoff example 3.0	3
Maximum Earthquake Magnitude Cutoff example 8.0	8.5
Enter Site Longitude (Degrees) example 115.0	117
Enter Site Latitude (Degrees) example 38.0	38

Any Changes? Y / N

Enter the longitude and latitude of a rectangle to bound the study area. This may be a smaller than the region chosen for the EARTHQUAKE SELECTION discussed previously. Consider the tectonics of the region in selecting bounds for the study. Be sure to include sufficient distance from the site so that all events which can cause significant ground motion at the site are included. Enter the MINIMUM MAGNITUDE CUTOFF, usually 3 since events less than 3.0 may not have been recorded and distortion of the recurrence estimation might result. Enter the MAXIMUM MAGNITUDE of the region.

As discussed above, enter the acceleration equation and hypocenter depth if needed, usually 10 miles. Enter the EXPOSURE PERIOD of the study in years.

1 Mc Guire

2 Trifunac and Brady

3 Campbell (Western US)

4 Campbell (Eastern US)

5 Donovan and Bornstein

6 Joyner and Boore

1

ENTER CHOICE FOR ACCELERATION EQUATION

Enter depth to hypocenter (miles) 0

Enter Exposure Perion (Years) 50
example 50.0

At this point you will be asked whether to use the earthquake data base or to use regional recurrence, A and B values. Enter Y to use the epicenter data. If N is entered enter the values of A and B as shown here:

Do you wish to compute recurrence data

from the epicenter data base (Y)es or (N)o

If you answer No, you must enter

Richter A and B values for the region

Your Choice? Y / N

Enter Richter A value 4.9
example 4.2

Enter Richter B value -.9
example -.85

Revise Data

The user may revise data once entered by selecting REVISE DATA from the REGIONAL STUDY window. The same questions given in SPECIFY DATA are asked with the previous responses. Advance through the data using the DOWN ARROW. Overwrite the revised value completely.

Begin Analysis

This choice begins the actual data search.

View Results

The VIEW RESULTS choice permits the user to see the output file from an analysis on the screen. It must be run after an analysis has been performed and data exists.

Print Results

PRINT RESULTS prints the output files. The output consists of a recurrence data, the regional recurrence coefficients, and the site probability distribution.

SAMPLE OUTPUT

M/DEG LONGITUDE	50.906
M/DEG LATITUDE	69.057
MAX LONGITUDE	73.000
MIN LONGITUDE	69.000
MAX LATITUDE	44.000
MIN LATITUDE	41.000
MIN MAGNITUDE	3.000
SITE LONGITUDE	71.000
SITE LATITUDE	42.500
EXPOSURE TIME	50.000
ACCELERATION EQUATION	.000

MAGNITUDE	NUMBER EVENTS GE M	NUMBER EVENTS/YR GE M
.10	10	.2564
.20	10	.2564
.30	10	.2564
.40	10	.2564
8.70	0	.0000
8.80	0	.0000
8.90	0	.0000
9.00	0	.0000

YEARS COVERED 39.00
RICHTER FIT EQ LOG10(N)=A + B*M

A = 3.698 B = -.909

REGIONAL PROBABILITY DISTRIBUTION

CONFIDENCE	ACCELERATION	MAGNITUDE	DISTANCE	LOWER CONF	UPPER CONF
.9900	.2276	5.5186	13.8088	.9705	.9965
.9802	.2086	4.8364	14.0230	.9537	.9918
.9704	.1973	5.2427	16.7578	.9390	.9864
.9608	.1796	5.6075	20.4107	.9254	.9805
.9512	.1500	4.9374	13.8097	.9125	.9742
.9418	.1461	5.0632	13.8910	.9002	.9677
.9324	.1425	5.4726	13.8134	.8883	.9610
.9231	.1397	6.0602	14.2851	.8768	.9541
.9139	.1371	5.0184	13.8089	.8656	.9485
.9048	.1356	5.2686	13.9865	.8547	.9402
.8958	.1301	4.2273	14.7429	.8440	.9331
.8869	.1300	4.7795	16.7417	.8335	.9260
.8781	.1282	4.6073	14.9659	.8233	.9188

.8694	.1262	5.2475	15.1447	.8133	.9117
.8607	.1239	5.5734	15.8349	.8034	.9044
.8521	.1237	5.3539	18.6373	.7939	.8972

```
                                 more

                        HISTOGRAMS  COVERING     5000.0 YEARS

 NO.   P(X)    F(X)    HISTOGRAM    MAGNITUDE
  86 .086   .086 3.307 *********************************************
 109 .109   .195 3.450 *********************************************
  73 .073   .268 3.593 *********************************************
  77 .077   .345 3.736 ************************************
  68 .068   .413 3.879 ************************************     more
  51 .051   .464 4.022 *********************************************
  66 .066   .530 4.165 *********************************************
  33 .033   .563 4.308 *********************************
  34 .034   .597 4.451 **********************************
  36 .036   .633 4.594 ************************************
  35 .035   .668 4.737 ***********************************
  36 .036   .704 4.880 ************************************
  33 .033   .737 5.023 *********************************
  31 .031   .768 5.166 *******************************
  20 .020   .788 5.309 ********************
                            more
 NO.   P(X)    F(X)    HISTOGRAM    ACCELERATION
 563 .563   .563  .007 *********************************************
 214 .214   .777  .021 ************************************     more
  86 .086   .863  .036 *************************************
  47 .047   .910  .050 *********************************************
  18 .018   .928  .064 ******************
  13 .013   .941  .079 *************
   9 .009   .950  .093 *********
   9 .009   .959  .107 *********
   6 .006   .965  .121 ******
   6 .006   .971  .136 ******
   4 .004   .975  .150 ****
   2 .002   .977  .164 **
   3 .003   .980  .179 ***
   2 .002   .982  .193 **
   2 .002   .984  .207 **
   1 .001   .985  .221 *
   0 .000   .985  .236
   2 .002   .987  .250 **
                        more
```

Plot File

This choice creates a plot of recurrence and site acceleration probability for the region. Figure 2 is an example plot.

Save Results

This choice permits the user to write the input, output and plot files to a named file of the user's choice. This prevents the files from being overwritten.

Response Plot

This choice creates a standard shaped site independent response plot on your plotting device, Figure 3. The user is requested to provide the base ground motion level in g's.

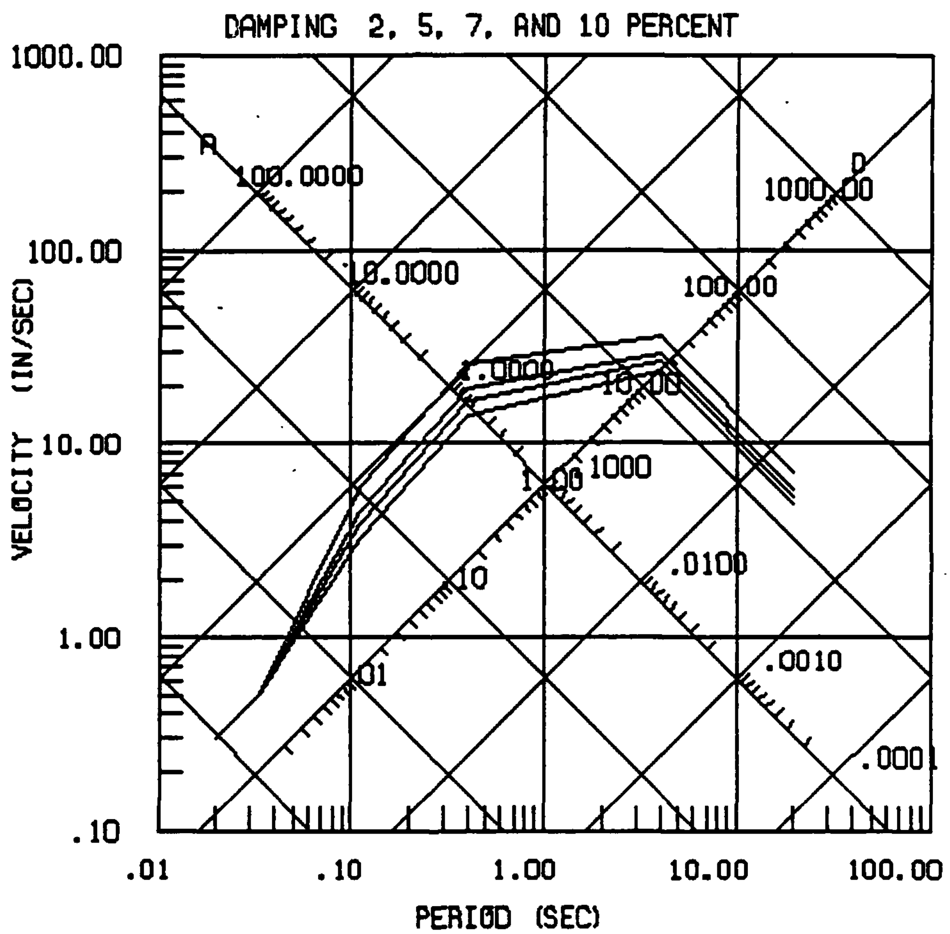


Figure 3. Typical response spectra.

FAULTS STUDY

For western sites where fault locations are known in more detail, a study can be performed by specifying the location of a fault in terms of coordinates of several points defining line segments. All earthquakes within a specified distance or boundary from the fault line under study are made a subset, and the recurrence of the fault is calculated. A probability analysis is then performed to calculate expected site acceleration and causative earthquake magnitude and epicentral distance for that fault. The program randomly selects the epicenter of an earthquake somewhere along the specified length of the fault. Using the fault recurrence data in terms of Richter coefficients and maximum earthquake magnitude associated with the fault, the program determines and earthquake magnitude and the length of fault break (assumed centered on the epicenter), and then calculates the distance of the site to the fault break (the epicentral distance and the hypocentral distance). These distances, along with the acceleration-magnitude attenuation relationship with its uncertainty defined by the standard deviation for that level of motion, give the site acceleration. The process is repeated using a Monte Carlo scheme to produce a list of site accelerations and related causative magnitude and epicentral distance thus defining the site's probability distribution. It is important to note that the program is random for each and every fault in the following:

a) Location along fault length, 2 dimensional
b) Magnitude shaped by recurrence coefficient
c) Acceleration level using mean and standard deviation relationship of magnitude - distance

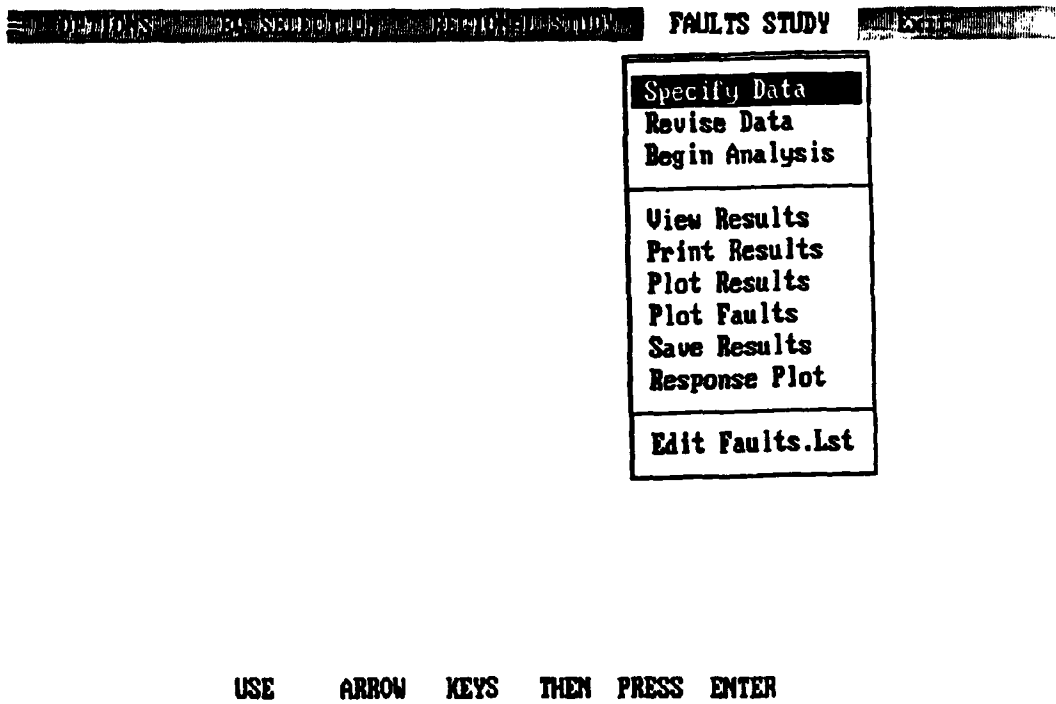
Provisions are included to use recurrence data from slip analysis or regional seismicity in lieu of fault specific data. The program determines, tabulates, and plots the probability of not exceeding various levels of acceleration in the time period specified. These data are available for all individual faults, and then are combined for all faults acting together. The determination of total risk to the site is of importance for establishing design levels.

A single recent large event may release strain built up over hundreds or thousands of years. As such, it might indicate a period of less activity in the immediate future. However, since the data base is relatively short, the return time for this event might be erroneously indicated as much less. For example, if this were a 500-year event and occurred during a 50-year data base its return might be estimated at 0.02 rather than 0.002. The plotted data points and line of best fit are determined by the computer analysis using regression analysis techniques. These should be reviewed and judgment used to adjust this type of datum point that will clearly plot significantly higher than the linear portion of the recurrence data.

The procedure is intended to be repeated several times,

during which the engineer can compare geologic data and lines of best fit from historic data and converge on the best estimate using his judgment.

The FAULTS STUDY window reveals the following choices:



Use the DOWN ARROW key and then choose REVISE DATA to see the example problem. Press RETURN to accept each value unchanged. Then select VIEW RESULTS from the window to see the output file on screen. Selecting PRINT RESULTS or PLOT RESULTS will print or plot the sample problem.

Specify Data

This is the data entry section for a new problem. Selecting this choice shows the following screen:

Enter Maximum Longitiude (Degrees) 120
example 120.0

Enter Minimum Longitude (Degrees) 114
example 112.0

Enter Maximum Latitude (Degrees) 42
example 40.0

Enter Minimum Latitude (Degrees) 36
example 34.0

Minimum Magnitude Cutoff 3
example 3.0

Enter Site Longitude (Degrees) 117
example 115.0

Enter Site Latitude (Degrees) 39
example 38.0

Enter Exposure Period (Years) 50
example 50.0

Any Changes? Y / N

Enter the longitude and latitude of a rectangle to bound the study area. This may be a smaller than the region chosen for the EARTHQUAKE SELECTION discussed previously. Consider the tectonics of the region in selecting bounds for the study. Be sure to include sufficient distance from the site so that all events which can cause significant ground motion at the site are included. Enter the MINIMUM MAGNITUDE CUTOFF, usually 3 since events less than 3.0 may not have been recorded and distortion of the recurrence estimation might result. Enter the EXPOSURE PERIOD of the study in years.

Enter the acceleration equation to use as discussed above.

1 Mc Guire

2 Trifunac and Brady

3 Campbell (Western US)

4 Campbell (Eastern US)

5 Donovan and Bornstein

6 Joyner and Boore

0

ENTER CHOICE FOR ACCELERATION EQUATION

The user is then given a menu of known faults in the California area. This menu is NOT complete; but is meant as a vehicle to reduce data entry. The user may add to this list; this will be discussed later.

SAN CLEMENTE
PALOS VERDE
NEWPORT-INGLEWOOD
ROSE CANYON
UNNAMED
ELSINORE
WHITTIER
SAN JACINTO
COYOTE CREEK
SUPERSTITION MT
SUPERSTITION HILL
IMPERIAL
BANNING
SAN ANDREAS
XY LOCAL
CRISTIANITOS
ALISO

Use the ARROW KEYS or press the first letter of the fault name desired to move throught the list. Press ENTER to select a fault; up to 15 faults may be selected.

The question is then asked whether to enter additional faults. If the answer is yes the following screen is shown:

Enter Fault Name example San Andreas	SAN CLEMENTE
Enter Maximum Magnitude example 7.0	7.2
Enter Characteristic Magnitude example 7.5	0
Enter Return Time in Years example 250.0	0
Enter Designator 1 or 2 or 3 1 for 2 line segment 2 for box segment 3 for specification of Richter A and B	3
Enter Depth to Hypocenter (miles) example 5.0	0

Any Changes? Y / N

Enter the name of the fault and the faults MAXIMUM MAGNITUDE. The CHARACTERISTIC MAGNITUDE is the magnitude which a geological evidence shows has a frequent history of occuring as a major event and the RETURN TIME requested is the return time of that event. This event is added to the seismicity computed by the historical data. The CHARACTERISTIC MAGNITUDE may exceed the MAXIMUM MAGNITUDE which is the cutoff for the recurrence calculation based on the historical data or the input coefficients.

The fault may be described by three choices:

1. A 2 line segment where events a specified distance from the fault's line segments are included in the subset of earthquake events used to calculate the recurrence of the fault.

2. A 2 line segment where earthquake events within a 4 sided region are used to calculate the recurrence of the fault.

3. A 2 line segment where the recurrence of the fault is specified in terms of the Richter A and B values.

Enter your choice for the specific fault being defined.

If you select 1:

The following questions will be asked

The following questions will be asked

Enter Point 1 Longitiude (Degrees) example 120.0	120
Enter Point 1 Latitude (Degrees) example 40.0	40
Enter Point 2 Longitude (Degrees) example 118.0	118
Enter Point 2 Latitude (Degrees) example 38.0	37.5
Enter Point 3 Longitude (Degrees) example 117.0	116.3
Enter Point 3 Latitude (Degrees) example 37.0	37
Distance from fault to include Events (miles) example 10.0	10

Any Changes? Y / N

These define the line segments and distance away from the fault, see Figure 4.

If you select 2:

The following questions will be asked as above.

Enter Point 1 Longitiude (Degrees) example 120.0	120
Enter Point 1 Latitude (Degrees) example 40.0	40
Enter Point 2 Longitude (Degrees) example 118.0	118
Enter Point 2 Latitude (Degrees) example 38.0	37.5
Enter Point 3 Longitude (Degrees) example 117.0	116.3
Enter Point 3 Latitude (Degrees) example 37.0	37

Additionally coordinates for a 4 sided region must be entered. Start with the uppermost right point and proceed CLOCKWISE. See Figure 5.

ENTER 4 POINTS FOR BOX STARTING AT UPPER RIGHT AND GO CLOCKWISE

Enter Point 1 Longitiude (Degrees) example 120.0	180
Enter Point 1 Latitude (Degrees) example 40.0	40
Enter Point 2 Longitude (Degrees) example 118.0	118.5
Enter Point 2 Latitude (Degrees) example 39.5	38
Enter Point 3 Longitude (Degrees) example 118.5	120.5
Enter Point 3 Latitude (Degrees) example 37.0	37.5
Enter Point 4 Longitude (Degrees) example 120.5	120
Enter Point 4 Latitude (Degrees) example 37.5	40

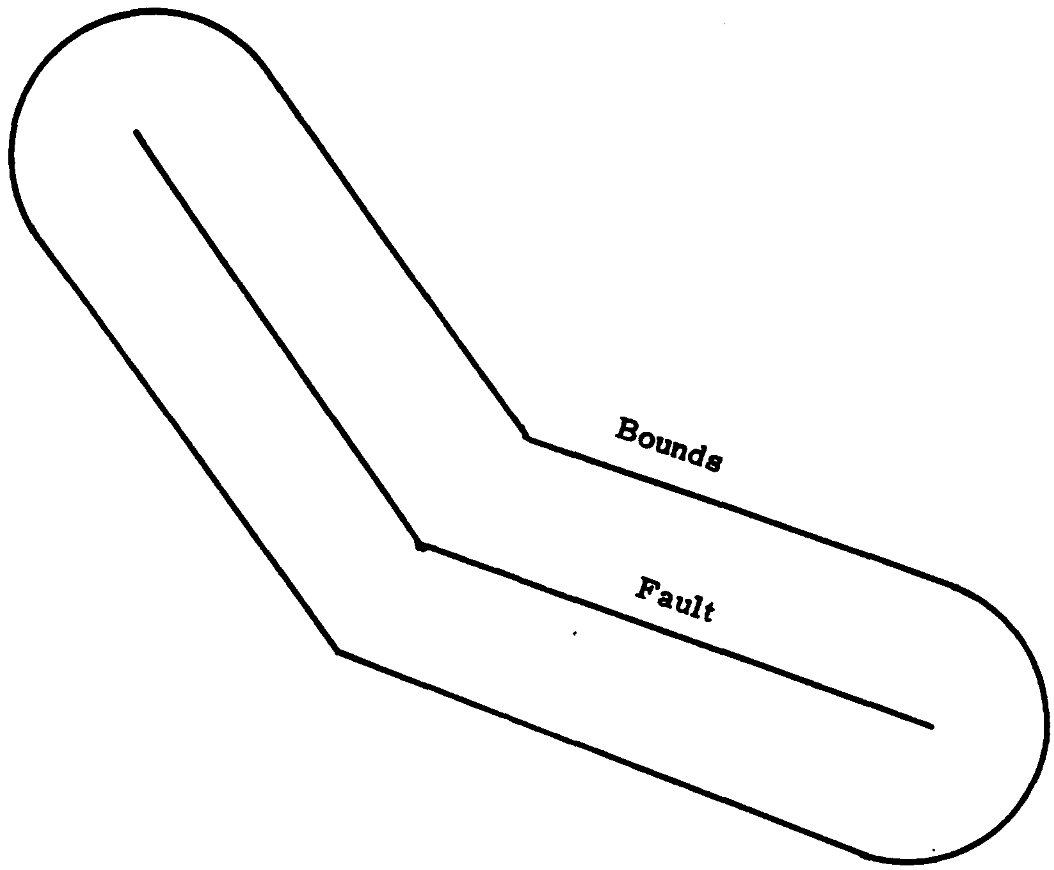


Figure 4. Two line segment model of fault with distance from fault shown.

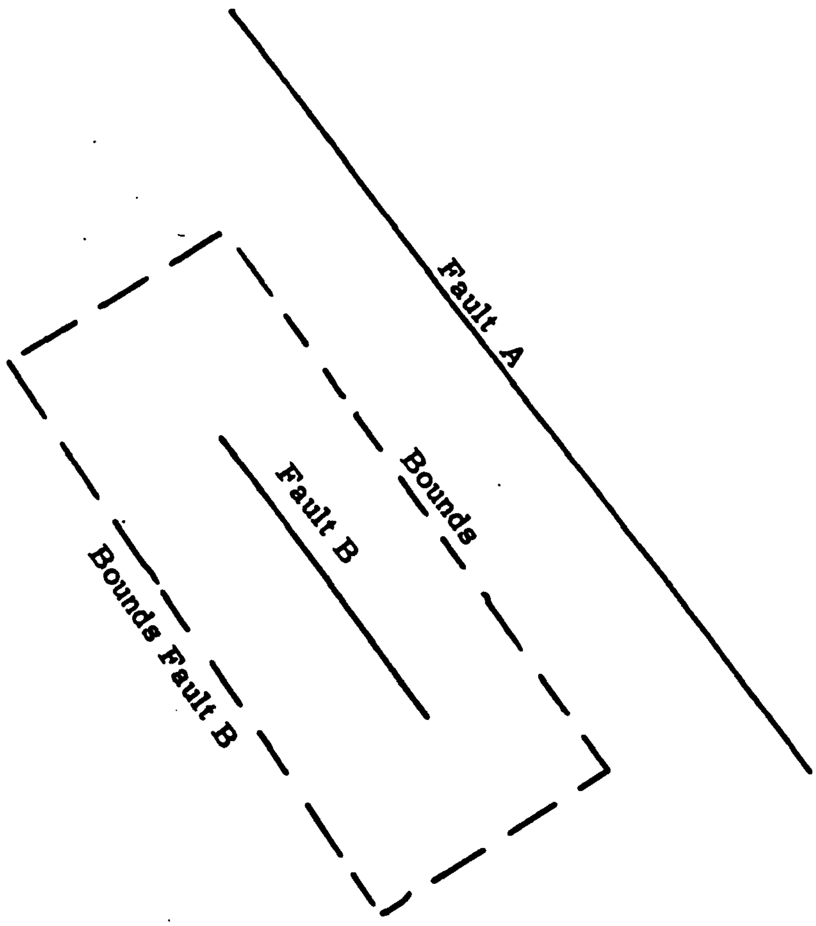


Figure 5. Two line segment of fault with surrounding 4-sided region.

If you select 3:

Enter the points for the 2 line segments as above.

Enter Point 1 Longitiude (Degrees) example 120.0	120
Enter Point 1 Latitude (Degrees) example 40.0	40
Enter Point 2 Longitude (Degrees) example 118.0	118
Enter Point 2 Latitude (Degrees) example 38.0	37.5
Enter Point 3 Longitude (Degrees) example 117.0	116.3
Enter Point 3 Latitude (Degrees) example 37.0	37

Any Changes? Y / N

Then enter the A and B values.

Enter Richter A for Fault example 4.8	4.9
Enter Richter B for Fault example -.89	-.9

Revise Data

The user may revise data once entered by selecting REVISE DATA from the FAULTS STUDY window. The same questions given in SPECIFY DATA are asked with the previous responses. The user may revise the data specified in the predefined faults list.

DO YOU WISH TO REVISE DATA FOR THE FAULTS

YOU SELECTED FROM THE PREDEFINED LIST

(Y)ES / (N)O

Selection of N for NO allows the user to accept or revise the selection of faults from the predefined list of faults in the menu. The data for these faults can not be revised for this choice. However, the user may revise the data for the faults he entered. Selection of Y for YES treats the predefined faults as if they were user entered and allows the user complete freedom to change all values. In editing faults the user may skip a fault by pressing the ESCAPE KEY after the fault name appears rather than the ENTER or DOWN ARROW KEY. This advances to the next fault leaving the previous fault's values unchanged.

NOTE AND WARNING

THE PREDEFINED FAULTS ARE REASONABLE FIRST ESTIMATES. THEY WILL NOT SUIT ALL CASE STUDIES. IN PARTICULAR, THE USER SHOULD PAY ATTENTION TO THE DEFINITION OF THE REGION SURROUNDING THE FAULT LINE TO INCLUDE EARTHQUAKE EPICENTERS FOR THE FAULT RECURRENCE RELATIONSHIP. THE INTENT IS TO INCLUDE ONLY THOSE EVENTS WHICH CAN BE ATTRIBUTED TO THAT FAULT AND EXCLUDE THOSE FROM OTHER FAULTS. BASED ON YOUR SPECIFIC PROBLEM IT MAY BE NECESSARY TO CHANGE THE SELECTION MODE FROM A STANDARD DISTANCE AWAY FROM THE FAULT TO A QUADRILATERAL DEFINITION. AFTER A PRELIMINARY ANALYSIS FIRST RUN SOLUTION, THE USER SHOULD EXAMINE EACH RECURRENCE CURVE AND INCORPORATE GEOLOGIC DATA. THE SLOPE OF THE RECURRENCE LINE SHOULD BE CHECKED TO INSURE IT PASSES THROUGH THE LINEAR PART OF THE EVENTS DATA. THE USER SHOULD REVISE THE FAULT DATA FOR THE ALPHA AND BETA COEFFICIENTS COMPUTED FROM THE INITIAL PRELIMINARY ANALYSIS. THIS ITERATION CONTROLS THE QUALITY OF THE ANALYSIS. THE ACCURACY OF THE ANALYSIS IS A FUNCTION OF THE EFFORT SPENT BY THE USER TO DEVELOP THE MODEL. THE PROGRAM HAS THE CAPABILITY OF PRODUCING HIGHLY ACCURATE RESULTS.

Begin Analysis

This choice begins the actual data search.

View Results

The VIEW RESULTS choice permits the user to see the output file from an analysis on the screen. It must be run after an analysis has been performed and data exists.

Print Results

PRINT RESULTS prints the output files. The output consists of fault recurrence data, the fault recurrence coefficients, and the fault and total site probability distribution.

SAMPLE OUTPUT

M/DEG LONGITUDE	57.710
M/DEG LATITUDE	69.057
MAX LONGITUDE	119.000
MIN LONGITUDE	115.000
MAX LATITUDE	34.500
MIN LATITUDE	32.000
MIN MAGNITUDE	3.000
SITE LONGITUDE	117.360
SITE LATITUDE	33.300
EXPOSURE TIME	50.000
ACCELERATION EQUATION	.000
SAN CLEMENTE	

INDIVIDUAL FAULT STUDY

FAULT COORDINATES

118.700	32.200
118.300	32.800
117.800	32.650

FAULT MAX CREDIBLE EARTHQUAKE 7.70

FAULT EPICENTERS

LONGITUDE	LATITUDE	MAGNITUDE	DIST	ACC
117.800	32.583	4.500	55.645	.018
117.833	32.800	4.000	44.015	.017
117.833	32.716	4.400	48.699	.020
117.866	32.800	3.100	45.221	.009

more

AVE ACCELERATION	.0110
MAX ACCELERATION	.0378

EARTHQUAKE RECURRENCE

MAGNITUDE	NUMBER EVENTS GE M	NUMBER EVENTS/YR GE M
.10	45	.6164
.20	45	.6164
.30	45	.6164
.40	45	.6164
8.70	0	.0000
8.80	0	.0000
8.90	0	.0000
9.00	0	.0000

YEARS COVERED 73.00

RICHTER EQUATION LOG10(N) = A +B M
A = 1.640 B= -.601

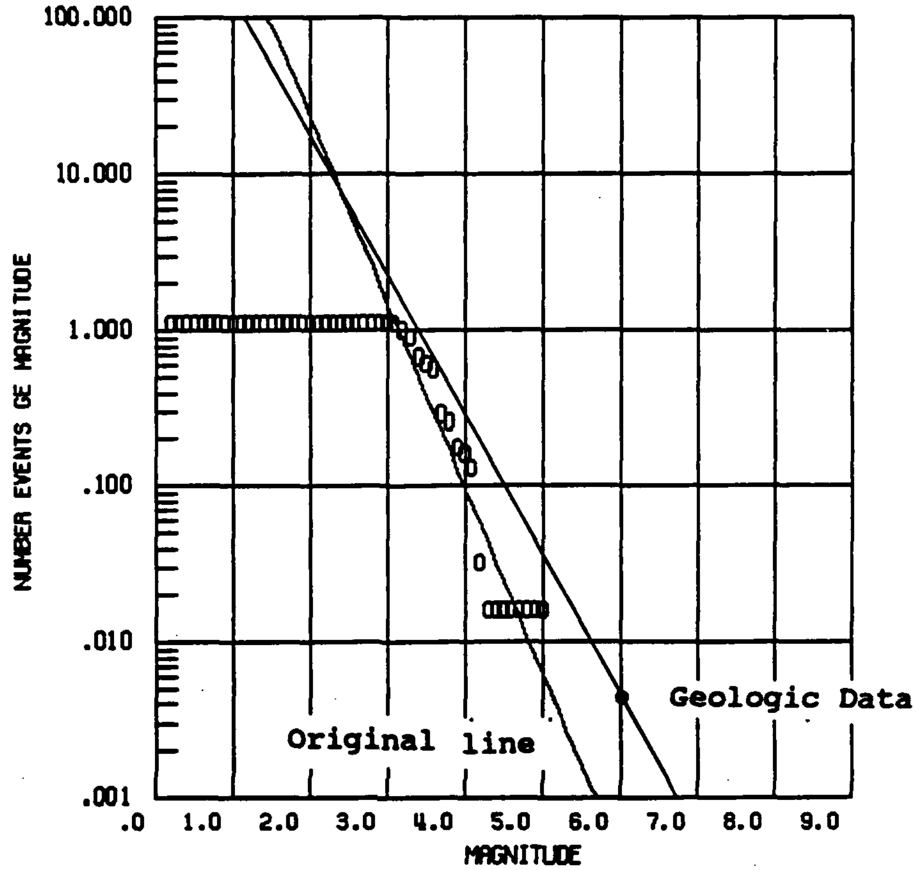
FAULT REGION ACCELERATION PROBABILITY

CONFIDENCE	ACCELERATION	MAGNITUDE	DISTANCE	LOWER CONF	UPPER CONF
.9900	.3014	7.2624	30.0969	.9705	.9965
.9802	.2364	6.7600	30.0901	.9537	.9918
.9704	.2084	6.0210	34.3689	.9390	.9864
.9608	.1984	7.3362	30.2334	.9254	.9805
.9512	.1799	6.7060	30.1197	.9125	.9742
.9418	.1795	5.9095	30.5953	.9002	.9677
.9324	.1606	6.6048	53.9805	.8883	.9610
.9231	.1571	7.4193	55.4437	.8768	.9541
.9139	.1548	6.9925	31.2901	.8656	.9485
.9048	.1306	6.7041	34.9663	.8547	.9402
.8958	.1292	7.5633	30.1013	.8440	.9331
.8869	.1287	5.6727	30.0893	.8335	.9260

A SIMILAR DATA TABULATION IS GIVEN
FOR THE TOTAL PROBABILITY ACCELERATION
FROM ALL OF THE FAULTS

Plot File

This choice creates a plot of recurrence and probability data for each fault and the total site probability of acceleration. Figure 6 is an example plot.



Note: The user should review the fit of the recurrence data shown by the line. This line should pass through the linear portion of the data. Sometimes when the number of events is limited or the minimum event is not specified the line may miss that region. The user should then rerun the problem revising the fault data by entering the A and B values from a new fit correctly through the data.

Figure 6a. Recurrence for a fault.

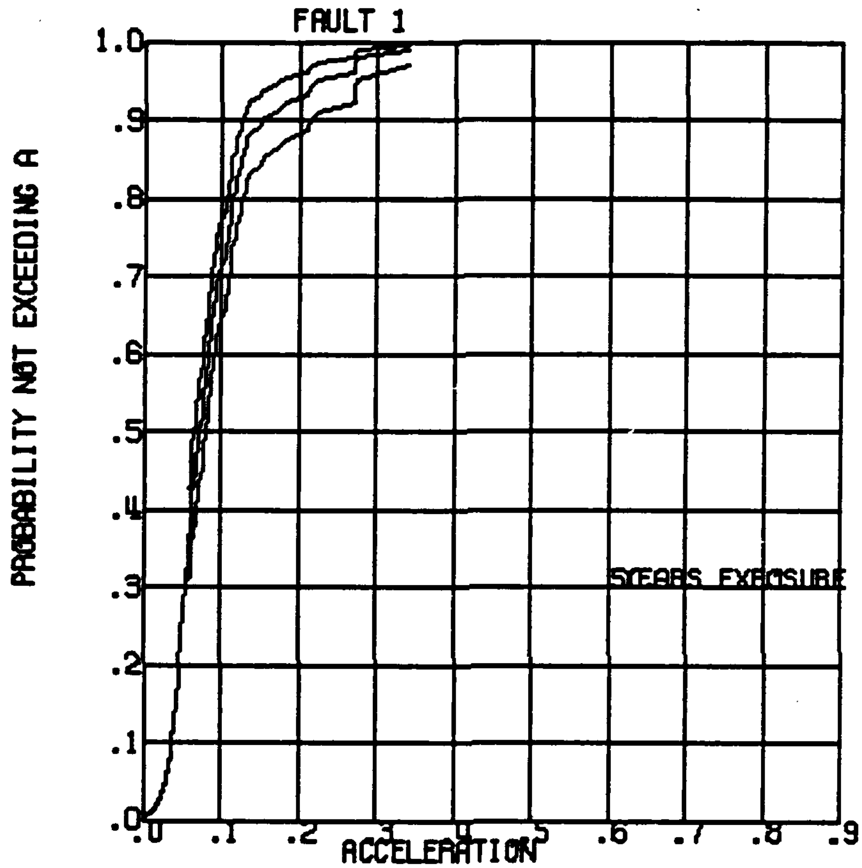


Figure 6b. Site acceleration probability from one fault.

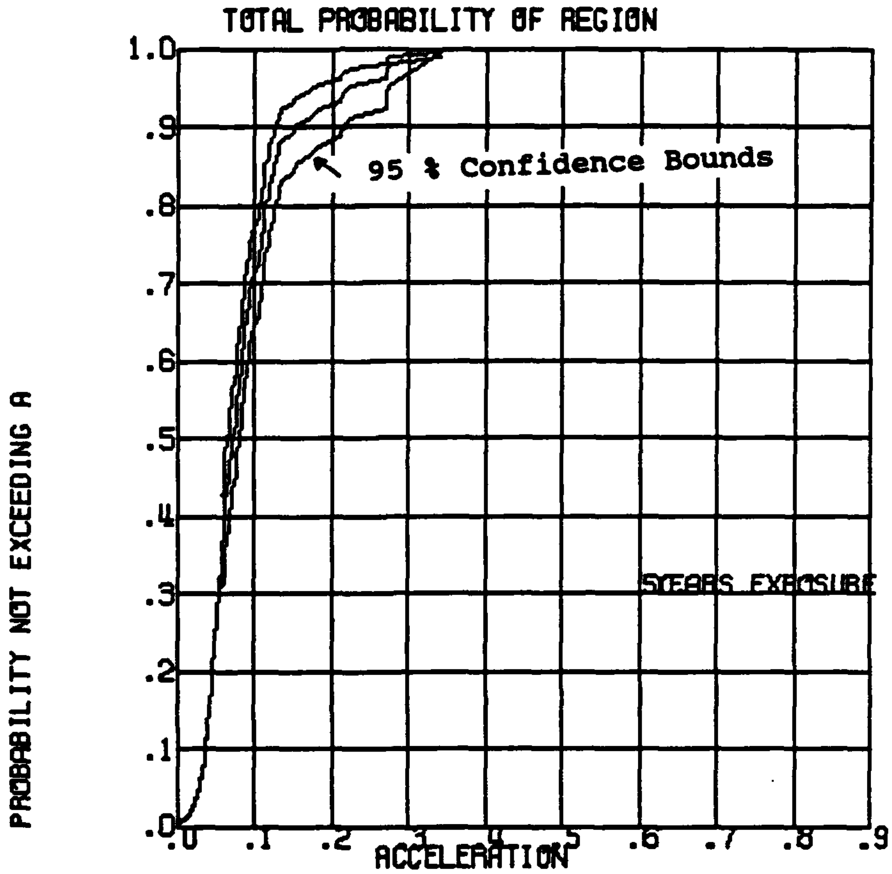


Figure 6c. Site acceleration probability from all faults.

Plot Faults

This choice creates a plot of the faults entered in the SPECIFY DATA or REVISE DATA option. The epicenters in the EQUAKES file are plotted also. This choice requires that the data be specified for the faults and the epicenter file be created. However the analysis need not be performed, so this may be used to check the events near faults.

The plotting procedure draws the grid of the region specified and then draws the faults and plots the epicenters. Often the fault extends beyond the region specified. IT IS NORMAL IN SUCH CASES TO SEE AN ERROR MESSAGE STATING UNPLOTTED VECTORS OR CLIPPED VECTORS for the elements which go beyond the plot boundaries.

Save Results

This choice permits the user to write the input, output and plot files to a named file of the user's choice. This prevents the files from being overwritten.

Response Plot

This choice creates a standard shaped site independent response plot on your plotting device, Figure 3. The user is requested to provide the base ground motion level in g's.

Edit Faults.Lst

This option permits the user to change the values of the data used to define the faults in the predefined faults list which appears as a menu from which the user may select faults for an analysis. Appendix A explains how to use this option and also explains how to calculate the recurrence coefficients, A and B from a recurrence plot. The appendix gives a list of faults and the recurrence plots for all the faults defined in the FAULTS.LST data file of predefined faults. The user may add to this list.

NOTE recurrence plots for faults with predefined recurrence coefficients are not plotted to save time; refer to Appendix A for the plots.

Discussion of Faults

Seismometers have been installed near known active faults to record microearthquakes. The events recorded range in magnitude from 0.5 to 1.5 and closely trace the faults. There are also regions where few microearthquakes occurred. The San Andreas fault north of the Sargent fault exhibits less activity than southern portions, perhaps indicating it is locked. However, sufficient microearthquakes have occurred to show the continuation of the fault. It may be reasoned that a small failure might occur before a major rupture occurs;alternatively, a large number of microearthquakes demonstrate active creep that may be sufficient to prevent sizable strain accumulation and preclude a large event.

Since earthquakes are associated with faults, it might be thought that epicenters should precisely overlay the fault location. This is not the case, because the distribution of seismometers is uneven and has changed with time. There are limitations in the accuracy of the techniques used to locate epicenters, principally from variations in assumed propagation velocities. Further explanation for the location of epicenters being off their associated fault comes from the simplified model used to locate them. The center of earthquake energy is located at the focus. For an inclined fault, the surface location (epicenter) is a distance removed from the surface fault location. It is only in vertical faults that one might expect the epicenter to lie on the fault.

Krinitzsky (1974) concludes that earthquakes can be related to existing faults and that the possibility of formation of new faults should not be considered in design. Large earthquakes require fault breaks of considerable distance. The uncertainties associated with earthquakes generated from faults not previously known can occur only for small events. Generally in the western United States, the extent of geologic investigation precludes a large fault from remaining unknown. However, there are uncertainties associated with eastern earthquakes. For example, causative faults responsible for the New Madrid earthquakes of 1811 and 1812 have not yet been identified. This may be the result of insufficient geologic investigations. The importance of considering the extent and quality of geologic investigations is evident.

A period of demonstrated quiescence over a geological time period indicates inactivity of the fault and probable continued inactivity. However, inactivity over a period of historic recording (50 to 100 years) does not imply future inactivity. Rather it may point to a "locked" region through which a major fault rupture may propagate. Two earthquakes to produce damage in southern California (Arvin-Tehachapi 1952; San Fernando, 1971) occurred on faults lacking major historic activity. With the exception of the San Jacinto fault system every known event greater than magnitude 6 in southern California has occurred on a fault without prior major historic activity. It must be

recognized that the accuracy of an incomplete data base is very limited when extrapolated for return period greatly exceeding the length of the period of recorded data. Furthermore, aftershocks must be distinguished from main shocks. An area having recently undergone a large event, which releases strain built up for hundreds or thousands of years, is probably safe against that size release in the near future. Thus a recent event on a fault might actually indicate safety in the immediate future rather than an indication of activity. A single event by itself cannot give an accurate measure of return time. The limitations of the historic data base can be reduced by considering the geologic data available to assist in the definition of fault activity.

Faults are classified into several types according to the relative displacement of the sides of the fault. Three principal types are normal, reverse, and strike-slip. The main fault may appear as a single break or as a parallel series of breaks. Surface rupture may or may not occur. Variations in displacement occur along the fault. Some fault displacement occurs continuously at a very slow rate and is termed as "creep". Creep rates have been established for some active faults in California. Estimates of earthquake recurrence can be sometimes made by observation of fault displacements of exposed layers in a trench. From age dating it is possible to identify the age of various strata and also to identify layer displacements.

ASSESSMENT OF GROUND MOTION ATTENUATION RELATIONSHIPS

A study was performed evaluating the significance and difference of available earthquake attenuation relationships. Data, although apparently plentiful, are actually very limited. Events are recorded by strong motion accelerographs often located within structures. The effect of the response of the structure often influences the reading. The assessment of the location and separation distance of many early recorded events is of questionable accuracy. Many researchers create subsets of the data often defining their own meanings to distance and magnitude and often limit the inclusion of records to specific conditions such as rock sites or events of only a limited magnitude range. Campbell (1982) for example computes in his relationship the average acceleration of the two horizontal directions. Campbell states that the maximum direction value should be 1.13 times the computed value. Joyner and Boore (1981) use the seismic moment as the basis for magnitude determination while Campbell uses local magnitude for events less than 6.0 and surface wave magnitude for events greater than 6.0. Each investigator uses judgment and perception of the elements incorporated into the formulation. This subjective approach makes seismic attenuation prediction more of an art since the scatter in the data is large. Recent work suggests that magnitude may not have the same significance for ground motion levels close to a fault as it does at greater distances. The analytical procedures generally assume motion to be related to magnitude and distance as independent variables. However, it is recognized that they are not independent. At close distances to the causative fault,

magnitude is not a controlling factor for ground motion in events of sufficient size with fault breakage over tens of kilometers in length. Local effects dominate at these close distances. It is at greater distances that magnitude assumes the usual significant role. However, the researcher must exercise care in treatment of this phenomena since an untendable position might occur that data could be extrapolated to show magnitude 7.0 events at close distances might produce lower ground motions than magnitude 6.0 events at the same distance.

It is significant that each of the researchers cited considers the uncertainty in the data and allows for computation of the standard deviation of the acceleration. This must be incorporated in risk analysis procedure and has been done in the computer programs.

A topic of discussion is the significance of peaks in accelerograms. It may be argued that these have little effect on the responses of a structure and that some measure of an effective acceleration should be used. Some suggest use of 0.65 times the peak represents an effective level. Others choose a more complex approach taking levels of motion which compose 90% levels of motion based on histogram distribution of all peaks in a record. Although such approaches are indeed based on fact that structures do not respond significantly to single peaks, they tend to ignore the usual engineering approach which utilizes a ground motion level to define a spectra. The spectra performs the function of giving an effective level of motion in the frequency response region of the structure. It is thus suggested that reduction of ground motion levels for use in creation of a spectra should not be done but rather the spectra will automatically perform this task. The risk analysis procedure in the program makes use of mean response data and the uncertainties such as occur in nature. To reduce the reported levels would be unconservative. It is substantially better to utilize a series of spectra from earthquake records to "average" effective acceleration levels rather than arbitrarily "throw away" a portion of the record. This is particularly significant since the engineering practice for scaling spectral values is in terms of peak values and until some other value is fabricated and agreed upon it will remain the only value clearly established to define the record. The engineer tasked with design applications must exercise caution in listening to the academics postulating improved techniques and not offering a corresponding basis for utilization of the existing spectral data base. Without a data base converted to some measured effective acceleration level the engineer would not be able to scale spectra and would be severely limited in characterization of a site.

Data reported by Chung (1978) was used in a study to compare computed and measured accelerations with distance. Records on buildings and vertical records were excluded. As can be seen, there is significant scatter. The standard deviation is:

Equation	Mean Deviation*	Standard Deviation
McGuire	-.005	.089
Trifunac and Brady	+.008	.105
Campbell (West)	-.059	.111
Campbell (East)	-.041	.101
Donovan and Bornstein	-.042	.104
Joyner and Boore	-.056	.111

* Minus = underestimates data.

The McGuire equation appears to have the best fit and least bias of the data. The analysis of the variances shows that there is a 90% confidence that the McGuire relationship shows a significant difference from the rest, that is that within the accuracy of the data the differences in equations is meaningful. However, strictly speaking, this comparison is not exact because differences exist in the definition of distances and magnitudes. Chang uses epicentral distance. This is not significant at large distances. In an attempt to determine the significance and sensitivity to definitions of distance and magnitude, the Joyner-Boore data base of 183 records was used for comparison (based on closest distance).

The data set used by Joyner and Boore was also studied. The mean and standard deviation of the equations are:

Equation	Mean Deviation*	Standard Deviation
McGuire	+.001	.0901
Trifunac and Brady	+.076	.1885
Campbell (West)	-.027	.0936
Campbell (East)	-.013	.0913
Donovan and Bornstein	-.014	.0844
Joyner and Boore	-.021	.0830

* Minus = underestimates data.

The McGuire equation has the least bias. The standard deviations except for the Trifunac and Brady equations are statistically about the same. It is not surprising that the Joyner and Boore equation fits this data best since it was formulated from the data.

The significance of selection of the earthquake attenuation equation is primarily in the determination of separation distances. McGuire and Donovan for example define the relationship in hypocentral distance, Trifunac and Brady in terms

of the epicentral distance and Campbell and Joyner and Boore in terms of the closest distance to the fault. For risk analysis of faults where the site tends to be located near one end of the fault the selection of a relationship based on the shortest distance will tend to give higher values. Caution should be used in selecting equations like Joyner and Boore or Campbell that utilize the shortest distance for use in regional studies involving floating earthquake epicenters (and not least distance to site). These relationships will report significantly lower accelerations that are not correct. To illustrate the significance of the attenuation relationship a study was made of a site 0.5-miles from the Hayward fault. Results for the 225-year return time are:

Joyner and Boore	.535g
Campbell	.540g
McGuire	.396g
Donovan and Bornstein	.382g

The first two use shortest distance; the last 2 use hypocentral distance. The hypocentral distance is thought to be a better representation. This example presents extreme conditions not usually encountered.

A study of the Monterey area was made. Six faults were considered; results are given as follows for the 225-year return time site acceleration composite risk from 6 faults:

McGuire	0.2802g
Joyner and Boore	0.3404g
Campbell	0.2832g

For comparison Thenhaus, et al. computes for the same site

100-year return time	0.20g
500-year return time	0.50 to 0.62g

The following projections can be made. The 100-year return time acceleration, 0.2g, has a 61% probability of not being exceeded in 50 years. This translates into a ratio of 0.70 of the 250-year return time acceleration. The projected 250-year acceleration would be .02/.07 or 0.286g. The 500 year return time acceleration, 0.5 - 0.62g, has a 90% probability of not being exceeded in 50 years. This translates into a ratio of 2.0 of the 250-year return time acceleration. The projected 250-year acceleration would be 0.5/2.0 to 0.62/2.0 or 0.25 - 0.31g. These results agree favorably with those computed by the program (McGuire) and suggest a value of about 0.28g. It can be seen that the Joyner and Boore value of 0.34, based on closest

distance of fault to site, produces more conservative results.

To summarize, all the above cited equations have been implemented into the program in a correct consistent manner as each author intended taking account of each authors definitions.

PROGRAM LIMITATIONS

The EARTHQUAKE SELECTION routine can process 20,000 epicenters to the file EQUAKES.

The REGIONAL STUDY can input 20,000 epicenters.

The FAULTS STUDY can input 20,000 epicenters and 30 faults. Each fault can have up to 5,000 epicenters associated with it.

To keep the computational process manageable within the limits of a desktop computer tradeoffs had to be made in Monte Carlo process. As can be seen the 95 percent confidence bounds increase as the probability of not exceeding the acceleration increase. This program is intended to give an estimation of earthquake motions up to the 90 percent probability of not being exceeded in 50 years with high confidence. This program is not intended to be used to predict 5,000 year or 10,000 year events.

The user constructs a model of the seismicity of a region to which epiceters are assigned, recurrence relationships computed and ground motion probabilities determined. It should be obvious that if the user fails to include sufficient fault definition the model will lack those details and their contribution to the site's expected motion. Regional studies can not be substituted for fault studies with the same level of accuracy. While this is a simple but accurate analytical tool in the hands of a trained engineer it can be misused by the uninformed.

WARNING

CHECK YOUR RESULTS TO INSURE LESS THAN 20,000 EVENTS WERE SELECTED.
The program will display the number of events selected and the number of events read. If 5000 events were read reduce your area if possible or break the analysis into 2 parts. Failure to do this will result in the omission of all events beyond the 5000 event limit thus reducing the coverage.

FOR THE ADVANCED USER

Data and Output Files

The following shows the input data files created and the output results files for each section of the program.

	INPUT	OUTPUT
CONFIGURATION		DEVICE.CFG
EARTHQUAKE SELECTION	ONE.IN	ONE.OUT
	EPICENTR.LST	ONE.PLT
	epicenters .EPC	EQUAKES

REGIONAL STUDY	TWO.IN EQUAKES	TWO.OUT TWO.PLT
FAULTS STUDY	THREE.IN FAULTS.LST	THREE.OUT THREE.PLT

Files with the extension .EPC are epicenter files. Files with the extension .IN are data files created by the program. Files with the extension .LST are files supplied to the user which the user can modify; these will be discussed later. Files with the extension .OUT are output files to be printed. Files with the extension .PLT are plot files.

When files are saved the above files are copied to disk with a new name specified by the user as follows:

EARTHQUAKE SELECTION		
	ONE.IN	XXXXXXXX.1IN
	ONE.OUT	XXXXXXXX.1OU
	ONE.PLT	XXXXXXXX.1PT
REGIONAL STUDY		
	TWO.IN	XXXXXXXX.2IN
	TWO.OUT	XXXXXXXX.2OU
	TWO.PLT	XXXXXXXX.2PT
FAULTS STUDY		
	THREE.IN	XXXXXXXX.3IN
	THREE.OUT	XXXXXXXX.3OU
	THREE.PLT	XXXXXXXX.3PT

The program is set to use the standard names in the left column. To restore a saved data, output or plot file for use copy the file to the standard name as follows:

```
COPY XXXXXXXX.1IN  C:\SEISMIC\ONE.IN

COPY XXXXXXXX.1PT  ONE.PLT
```

Note that the INPUT files are stored in the PROGRAM DIRECTORY and the OUTPUT and PLOT files are stored in the DATA/RESULTS DIRECTORY. The program will re-run or revise the last case executed with the standard names. To revise or re-run a case, only the INPUT file (.IN) need be copied to the standard name.

Epicenter Files

The epicenter data base is broken down into separate files covering small regions to minimize search time. The user may add to the list of epicenter file by editing the file EPICENTR.LST which contains the number of files and for each epicenter file in the data base the file description and file name.

```
Number of Epicenter Files
Description , xxxxxxx.EPC
```

The epicenter data files contain data in the following format:

Year	Col 5	to	Col	8	F4.0
Latitude	Col 20	to	Col	24	F5.3
Longitude	Col 26	to	Col	31	F6.3
BM Body Magnitude	Col 36	to	Col	38	F1.2
SM Surface Magnitude	Col 54	to	Col	55	F1.1
OM Other Magnitude	Col 61	to	Col	63	F1.2
LM Local Magnitude	Col 83	to	Col	85	F1.2

Note no decimal points used.

REFERENCES

Campbell, K.W. (1982). "A preliminary methodology for the regional zonation of peak ground acceleration," in Proceedings of the Third International Earthquake Microzonation Conference, June 1982. Seattle, WA., University of Washington, 1982.

Chung, F. K. (1978). MPS73-1 State of the art for assessing earthquake hazards in the United States catalogue of strong motion eartquake records, Wtaerways Experiment Station, Vicksburg, MS, April 1978

Donovan, N.C. and Bornstein, A.E. (1978). "Uncertainties in seismic risk procedures," Journal of the Geotechnical Engineering Division, American Society of Civil Engineers, no. 103, pp 869-887.

Gutenberg, B and Richter, C.F. (1954)/ Seismicity of the earth and associated phenomena, 2nd edition. Princeton, NJ, Princeton University Press, 1954.

Joyner, W. B. and Boore, D. M. (1981). Peak horizontal acceleration and velocity from strong-motion records including records from the 1979 Imperial Valley, CA, earthquake, Bulletin Seismological Society of America, no. 71, pp 2017-2038.

Krinitzsky, E. (1974). Fault assessment in earthquake engineering, Army Engineering Waterways Experiment Station, Miscellaneous Paper S-731. Vicksburg, MS, May 1974.

McGuire, R. K. (1978). "Seismic ground motion parameter relations," in Proceedings of American Society of Civil Engineers Journal Geotechnical Engineering Division, no. 104, pp 481-490.

Richter, C. F. (1958). Elementary seismology. San Francisco, CA, W. H. Freeman Co., 1958, pp 768.

Trifunac, M. D. and Brady, A. G. (1975)/ " On the correlation of peak acceleration of strong motion with earthquake magnitude, epicentral distance and site conditions." in Proceedings of the U. S. National Conference on Earthquake Engineering, Ann Arbor, MI, University of Michigan, 1975.

Seismic Hazard Analysis

Appendix

Fault Data Base

THE FAULTS.LST FILE

The FAULTS.LST file contains a list of over 60 faults in California whose location and recurrence have been defined. This list is meant as a starting point and is by no means complete. The values used are based on seismicity studies conducted of various regions of California. The values are best estimates based on the data available at the time they were made. Program users are encouraged to review the data and change the values based on more current data. To edit the data select the EDIT FAULTS.LST option from the FAULTS STUDY menu.

The user may advance through the list by pressing the ESCAPE KEY; once the fault to be revised is found, press ENTER and move through the data using the ARROW KEYS; enter the revised numbers and proceed through the list. The program writes the old version of the list to a file labeled FAULTS.BAK as a precaution.

The remainder of this appendix gives a procedure to calculate the Richer recurrence coefficients, A and B from the recurrence plots. Note the program will attempt to fit the recurrence data calculated from the fault events as best as possible. The recurrence line should pass through the linear portion of the data and usually have a B value, slope of the line, on the order of -.90, the minus indicating downward direction. Use this as a guide in evaluating the computer results. The computer generated recurrence line is controlled by the minimum magnitude allowed in the analysis and the distance parameter which controls which and how many events to include in the calculation of recurrence for that fault. When geologic data is available, plot the data on the recurrence plot. Then move the line upward at the proper slope to include the geologic data points to increase fault recurrence if the geologic data so indicates.

The program gives the user a great deal of flexibility in producing a valid analysis. Care must be exercised to develop the correct seismic model of the earthquake activity of a region.

Format of FAULTS.LST

The format for the file is as follows

Number of Faults

For each fault Line 1
Fault Name

For each fault Line 2
Maximum Magnitude, Characteristic Magnitude, Return time
Hypocenter depth (miles)
FAULT TYPE (1 ,2 or 3)
Longitude Point 1

Latitude Point 1
Longitude Point 2
Latitude Point 2
Longitude Point 3
Latitude Point 3
Distance From Fault (miles) for Type 1 or A value
for Type 3
0 for type 1 or B value for Type 3
Characteristic Magnitude
Return Time for Characteristic Magnitude

Line 3 If FAULT TYPE is 2 Define Box clockwise from upper right

Longitude Point 1
Latitude Point 1
Longitude Point 2
Latitude Point 2
Longitude Point 3
Latitude Point 3
Longitude Point 4
Latitude Point 4

Computation of A and B values is illustrated by the following:

$\log_{10}(N) \;=\; A + B*M$

$A \;=\; \log_{10}$ (intercept at M=0) $M = 0$ $N = 112$

$A \;=\; \log_{10}(112) \;=\; 2.04921$

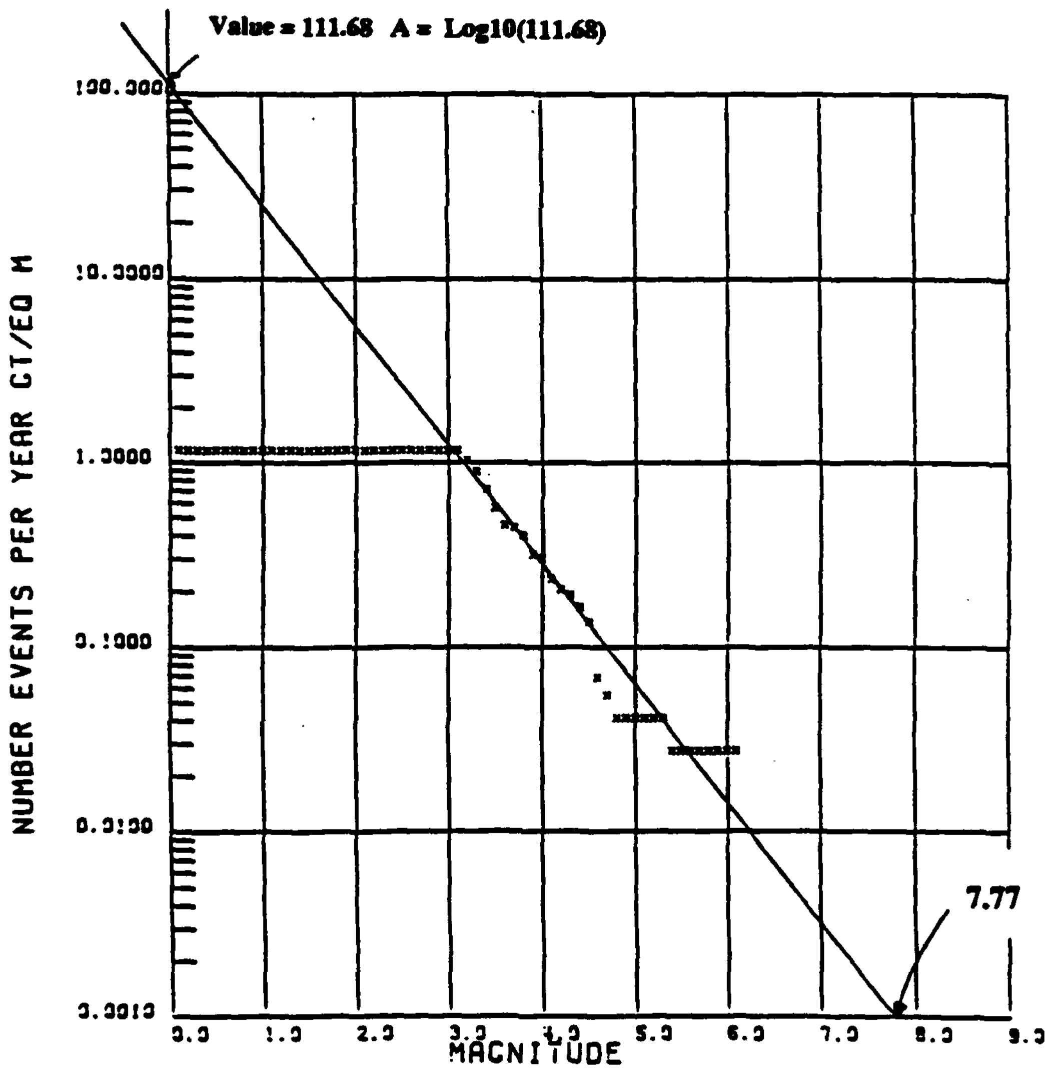
$B \;=\;$ slope of line (must be negative)

$$B = \frac{\log_{10}(112) - \log_{10}(.001)}{7.77 - 0} = \frac{2.04921 - (-3)}{7.77}$$

$B \;=\; 0.65$

$B \;=\; -0.65$ negative decreasing

$$B = \frac{A + 3}{\text{Magnitude at .001 intercept}}$$



List of Faults contained in FAULTS.LST

1	SAN CLEMENTE
2	PALOS VERDE
3	NEWPORT-INGLEWOOD
4	ROSE CANYON
5	UNNAMED (Offshore N of San Diego)
6	ELSINORE
7	WHITTIER
8	SANTA CRUZ ISLAND
9	SAN JACINTO
10	COYOTE CREEK
11	SUPERSTITION MT
12	SUPERSTITION HILL
13	IMPERIAL
14	BANNING
15	SAN ANDREAS (South)
16	MALIBU RAYMOND
17	PINTO MOUNTAIN
18	SANTA SUSANA+SIERRA MADRE
19	SAN GABRIEL
20	HELENDALE
21	LOCKHART
22	LENWOOD
23	HARPER
24	CAMPROCK
25	EMERSON
26	BLACKWATER
27	PISGAH
28	GREEN VALLEY & CONCORD
29	MONO LAKE & HILTON
30	INYO MOUNTAIN
31	UN-NAMED 3
32	BLUE CUT
33	LUDLOW
34	GARLOCK
35	PARAMINT ZONE
36	DEATH VALLEY
37	FURNACE CREEK
38	LIKELY FAULT
39	SURPRISE
40	SANTA YNEZ
41	BIG PINE
42	UN-NAMED 1
43	UN-NAMED 2
44	SAN ANDREAS (Central)
45	CALICO
46	OAKRIDGE
47	SAN CAYETANO+ARROYO PARIDA
48	PINE MOUNTAIN
49	OZENA
50	WHITE WOLF
51	PLEITO
52	SAN JUAN
53	SIERRA NEVADA
54	OWENS VALLEY
55	SAN ANDREAS (San Francisco)
56	ORTIGALITO
57	HEALDSBURG
58	HAYWARD
59	SAN GREGORIO
60	HOSGRI
61	RINCONADA
62	CALAVERAS
63	SAN ANDREAS (North & Offshore)
64	MENDOCINO

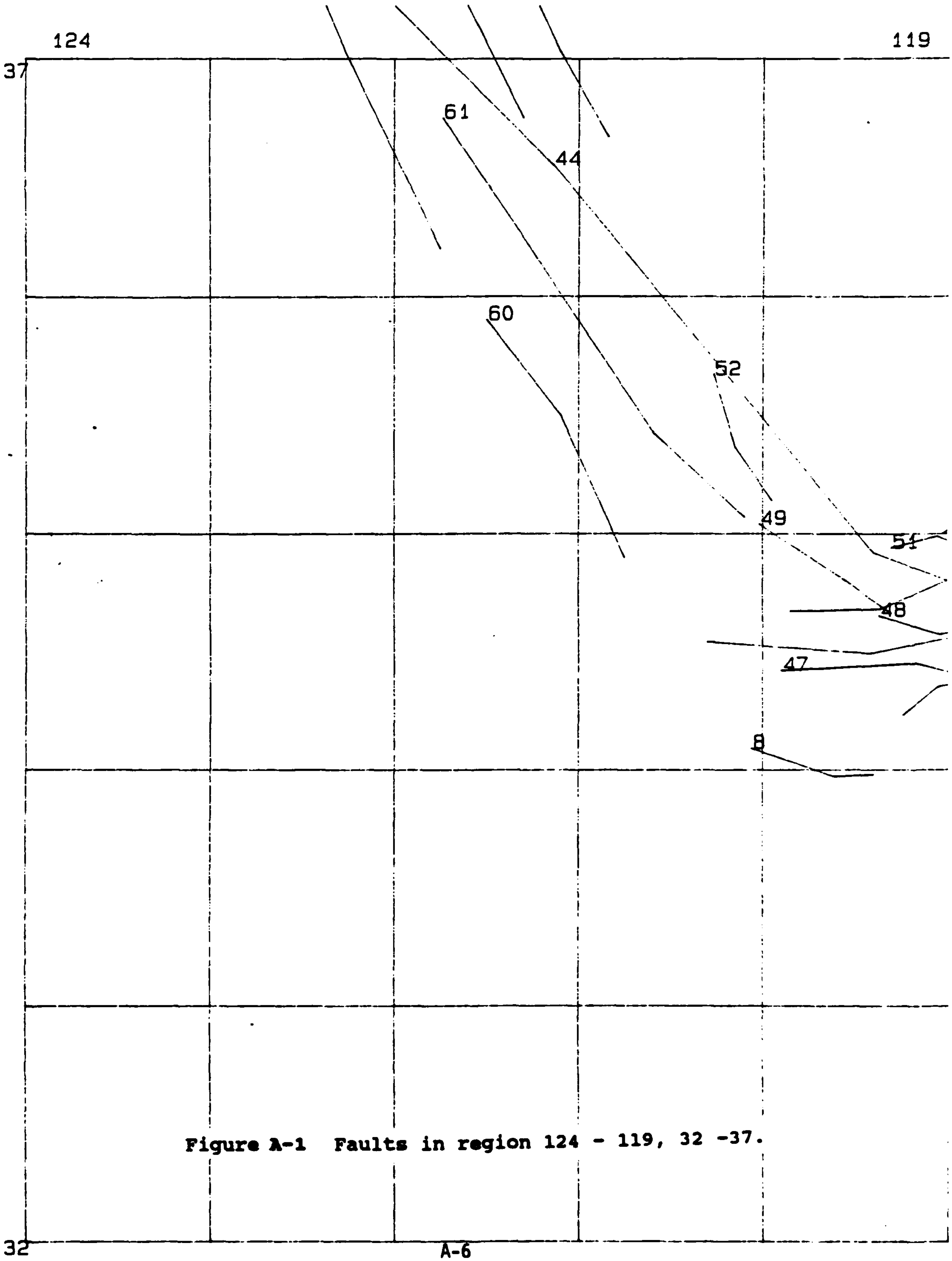


Figure A-1 Faults in region 124 - 119, 32 -37.

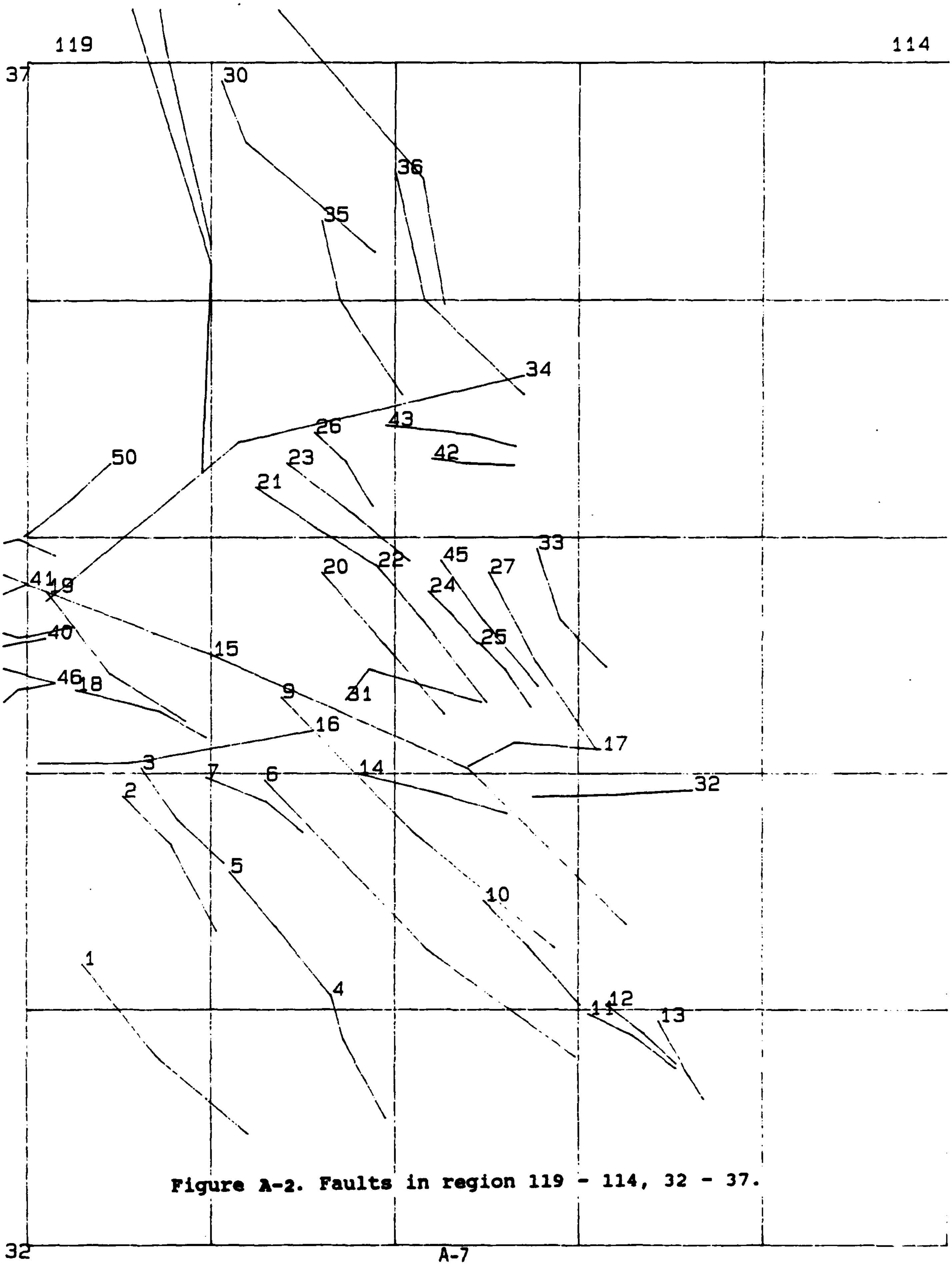


Figure A-2. Faults in region 119 - 114, 32 - 37.

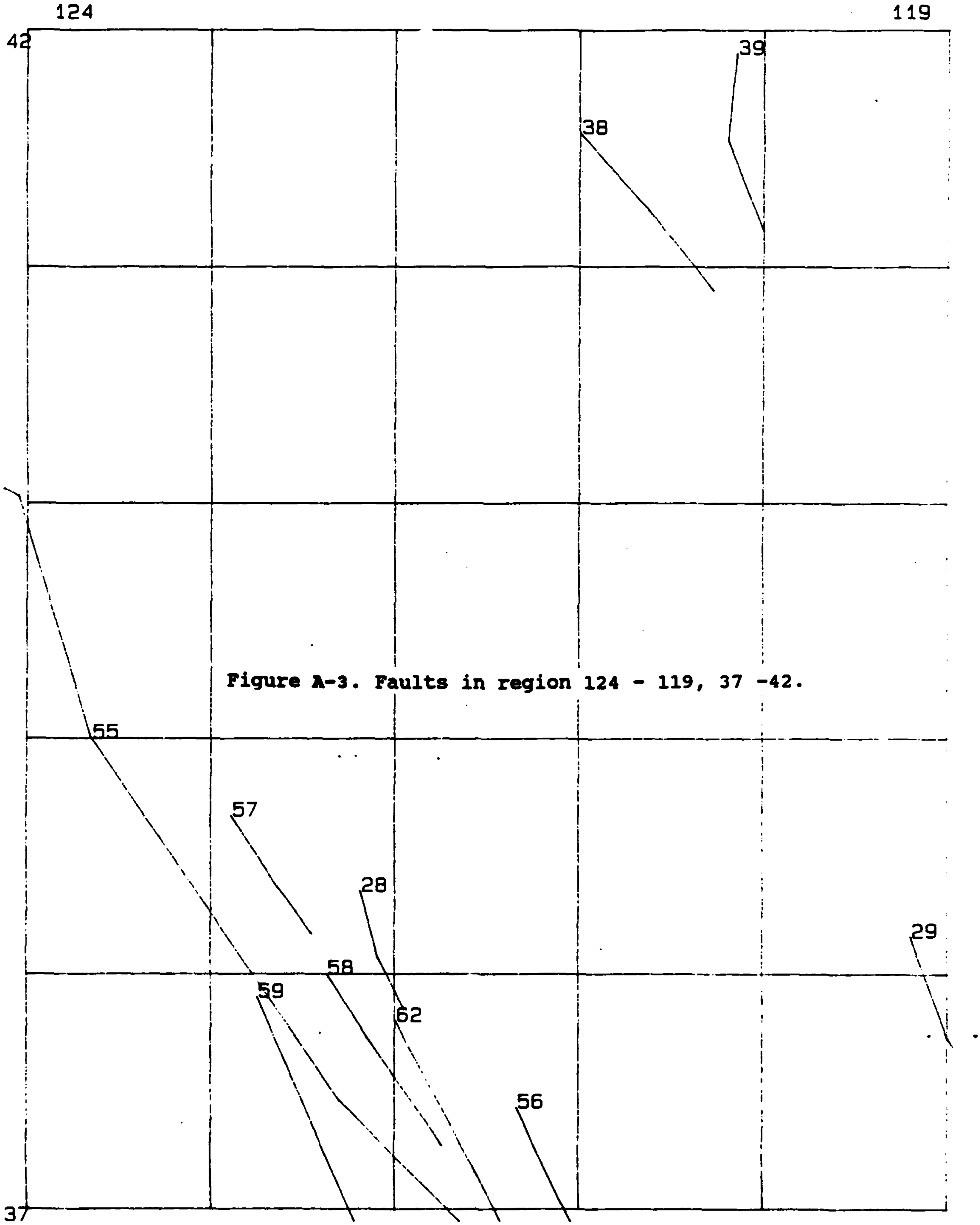


Figure A-3. Faults in region 124 - 119, 37 -42.

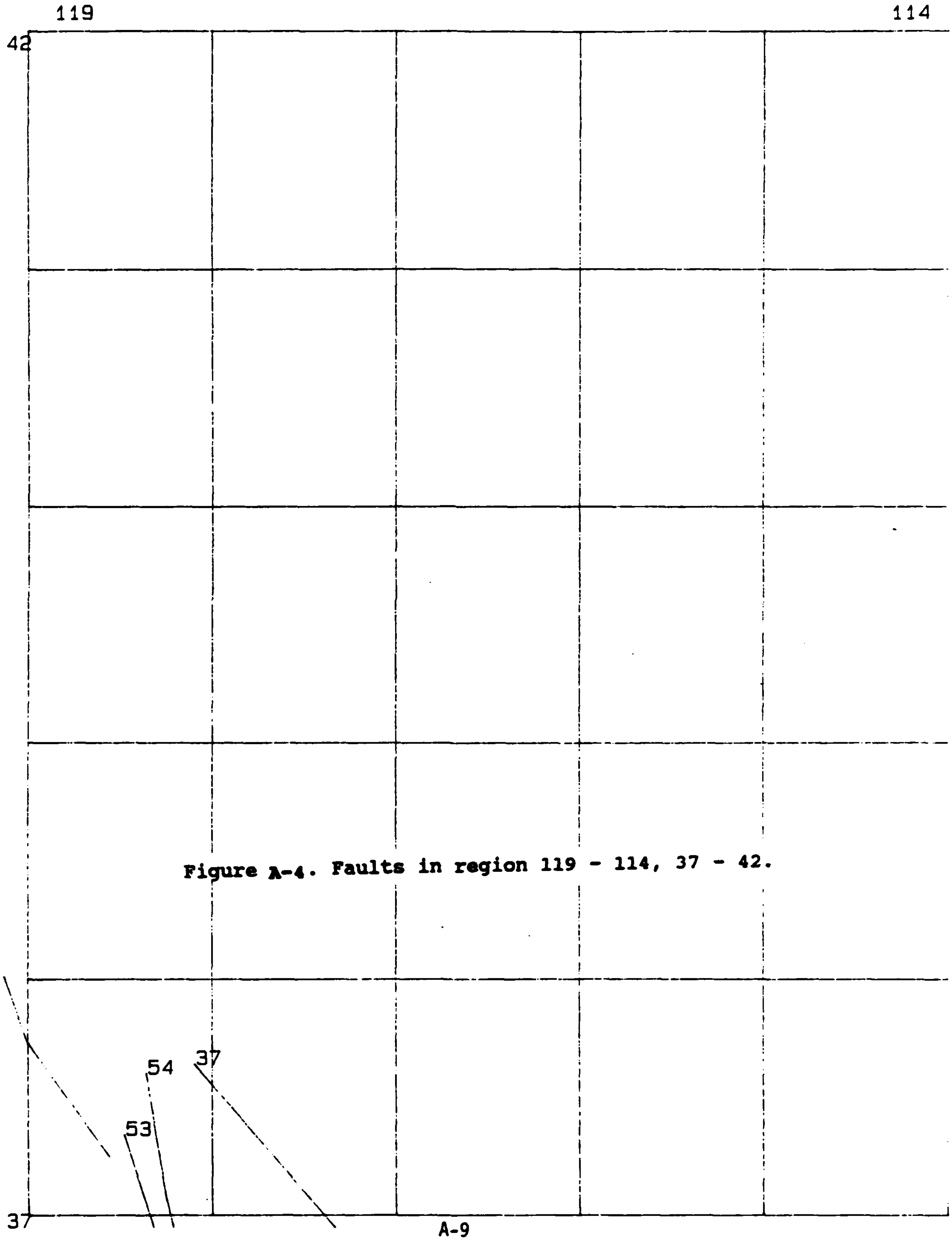
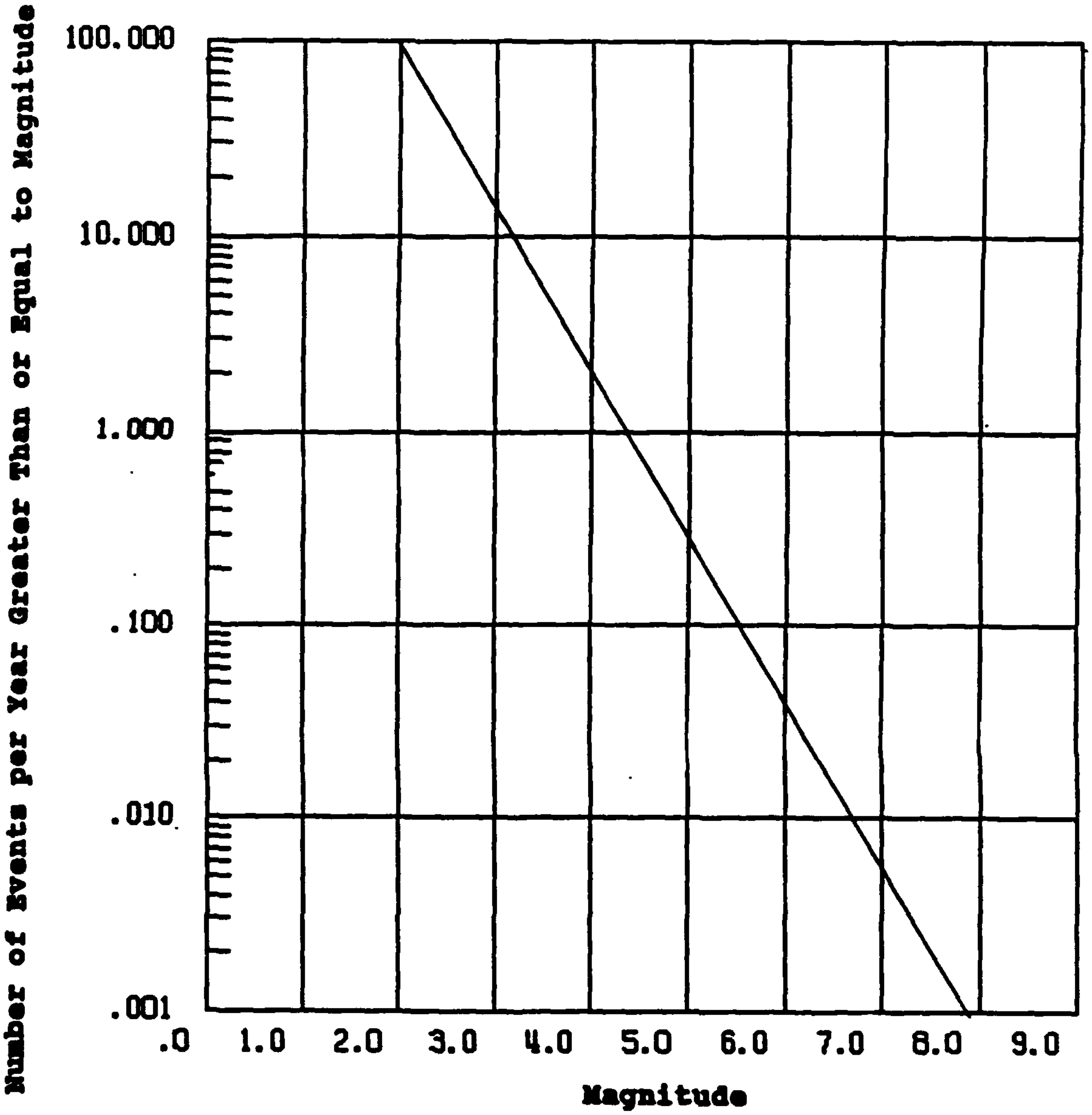


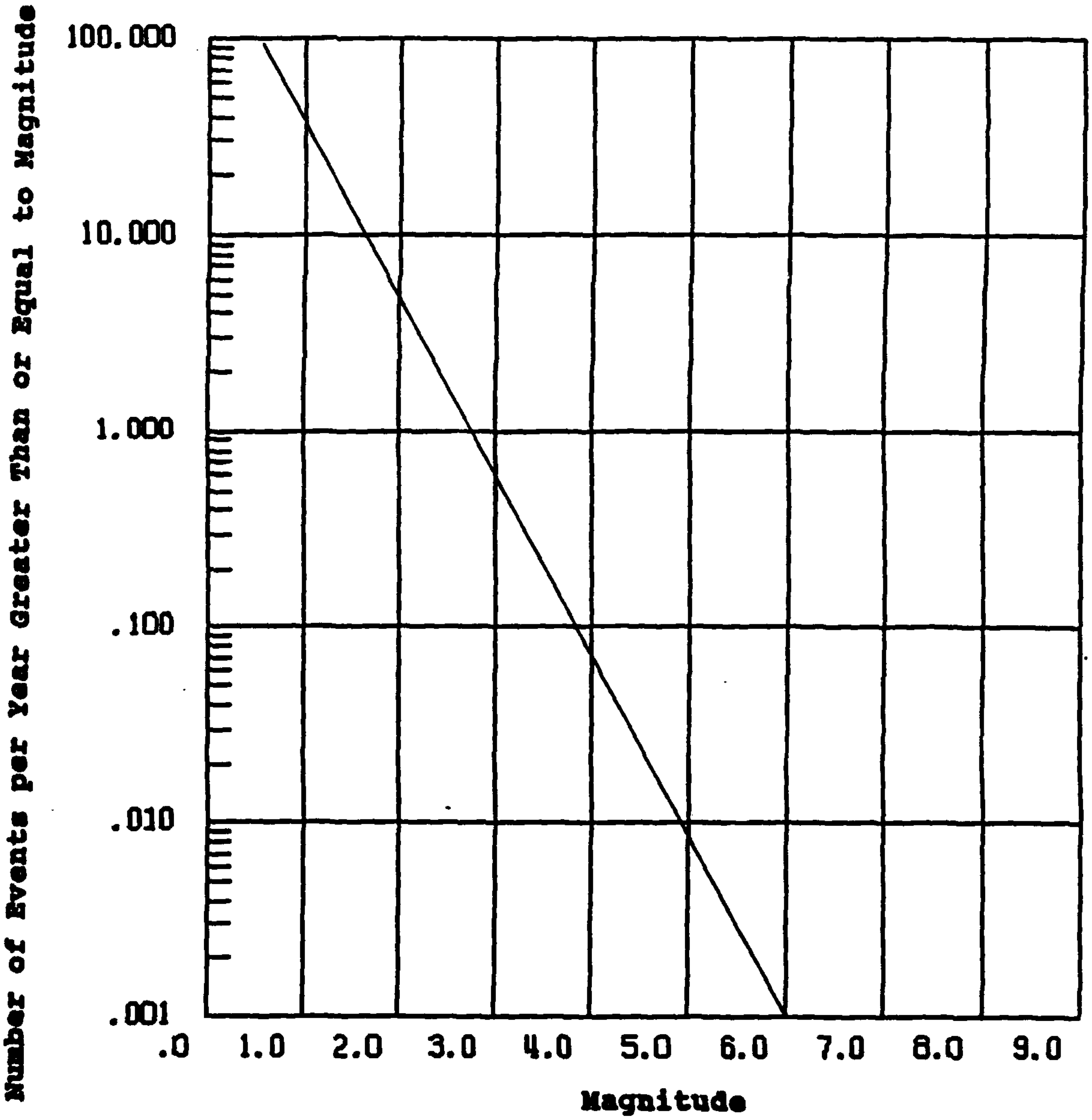
Figure A-4. Faults in region 119 - 114, 37 - 42.



Fault - BANNING **Maximum Magnitude 7**

Fault Longitude / Latitude Coordinates
PT1 117.21 , 34 PT2 116.79 , 33.92 PT3 116.39 , 33.83

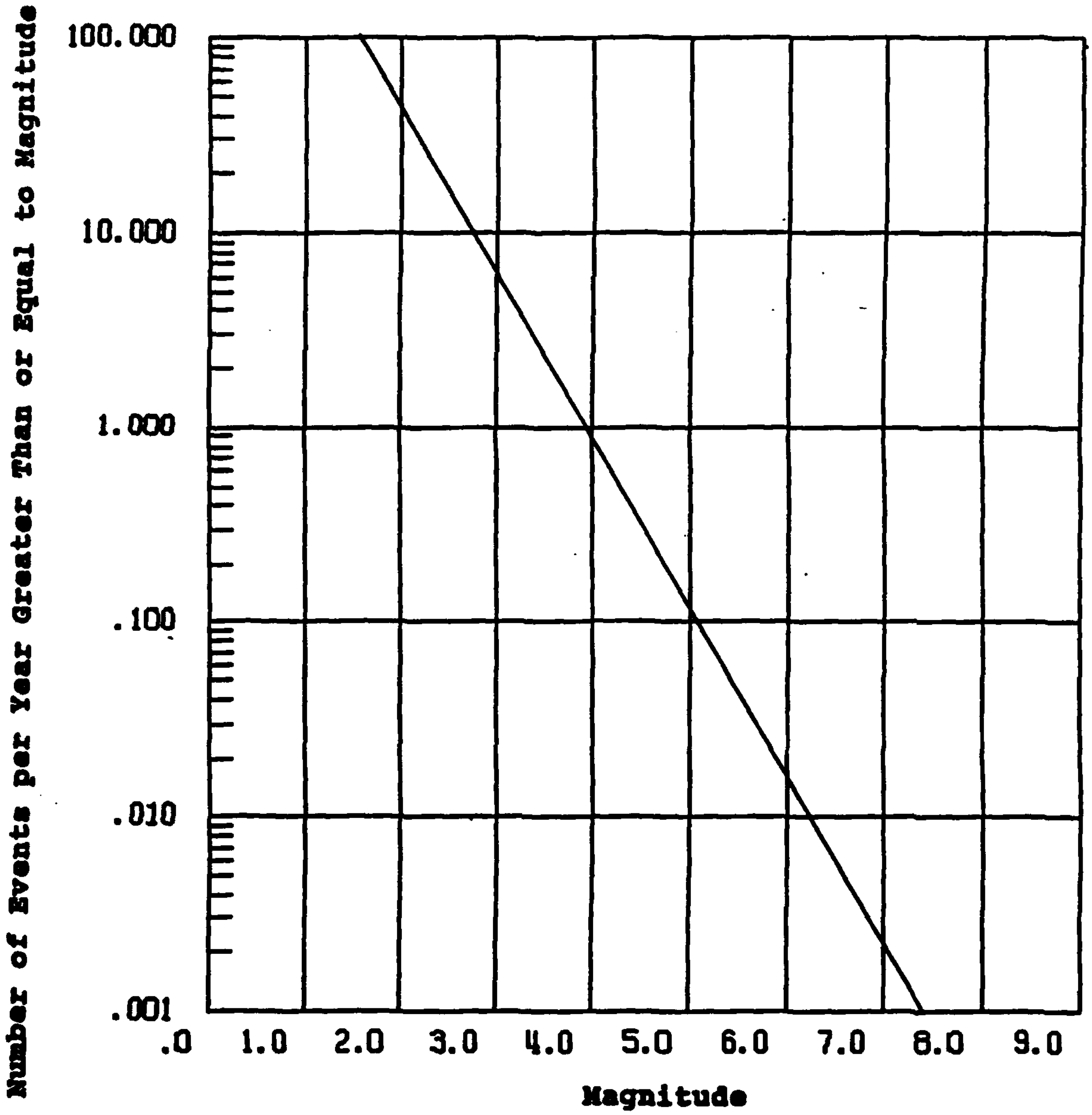
Figure A-5 . Fault recurrence.



Fault - BIG PINE Maximum Magnitude 7.6

Fault Longitude / Latitude Coordinates
PT1 119.85 , 34.67 PT2 119.36 , 34.68 PT3 119 , 34.8

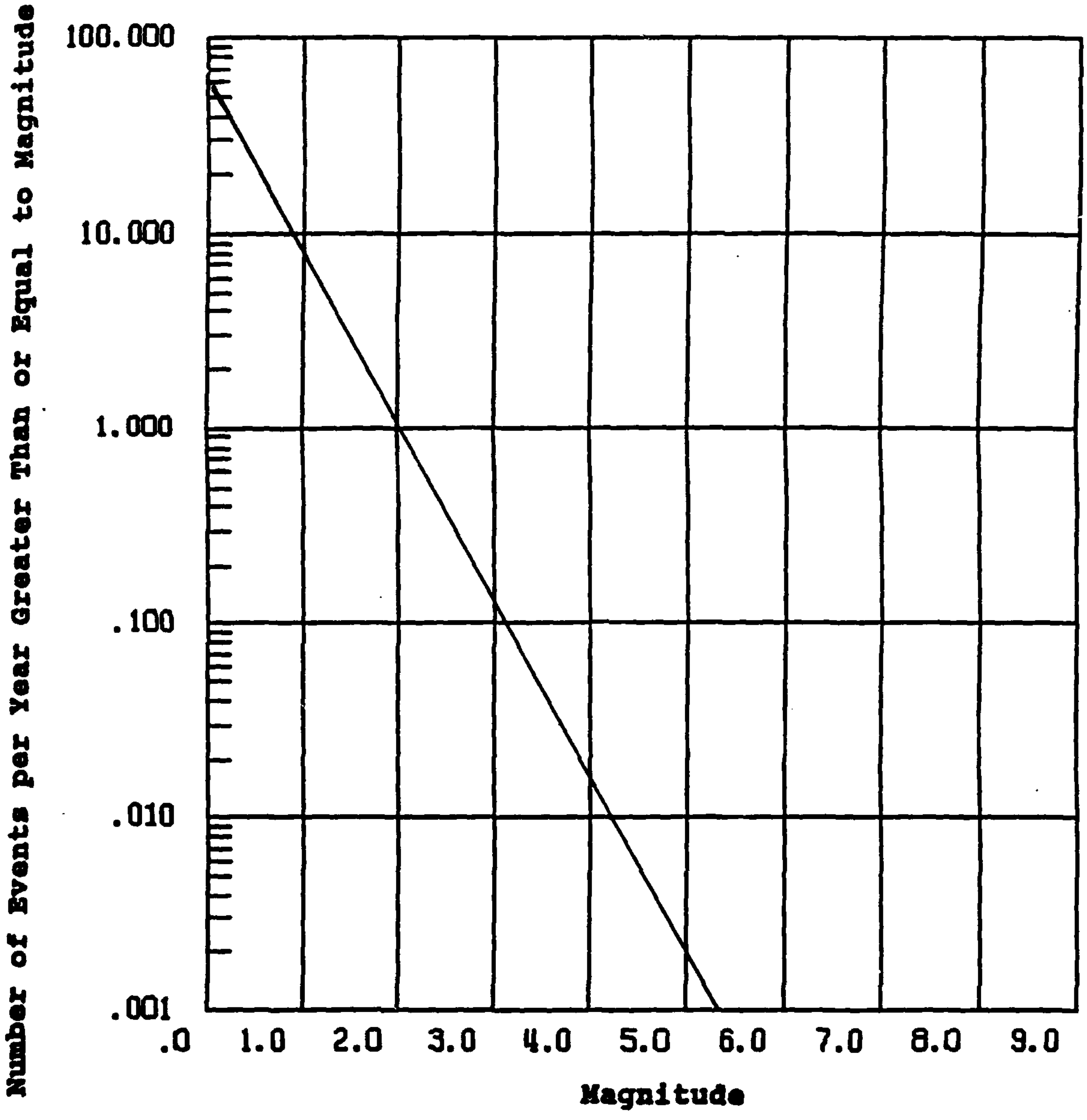
Figure A-6 . Fault recurrence.



Fault - BLUE CUT   Maximum Magnitude 7

Fault Longitude / Latitude Coordinates
PT1 116.25 , 33.9   PT2 115.79 , 33.91   PT3 115.38 , 33.93

Figure A-7 . Fault recurrence.



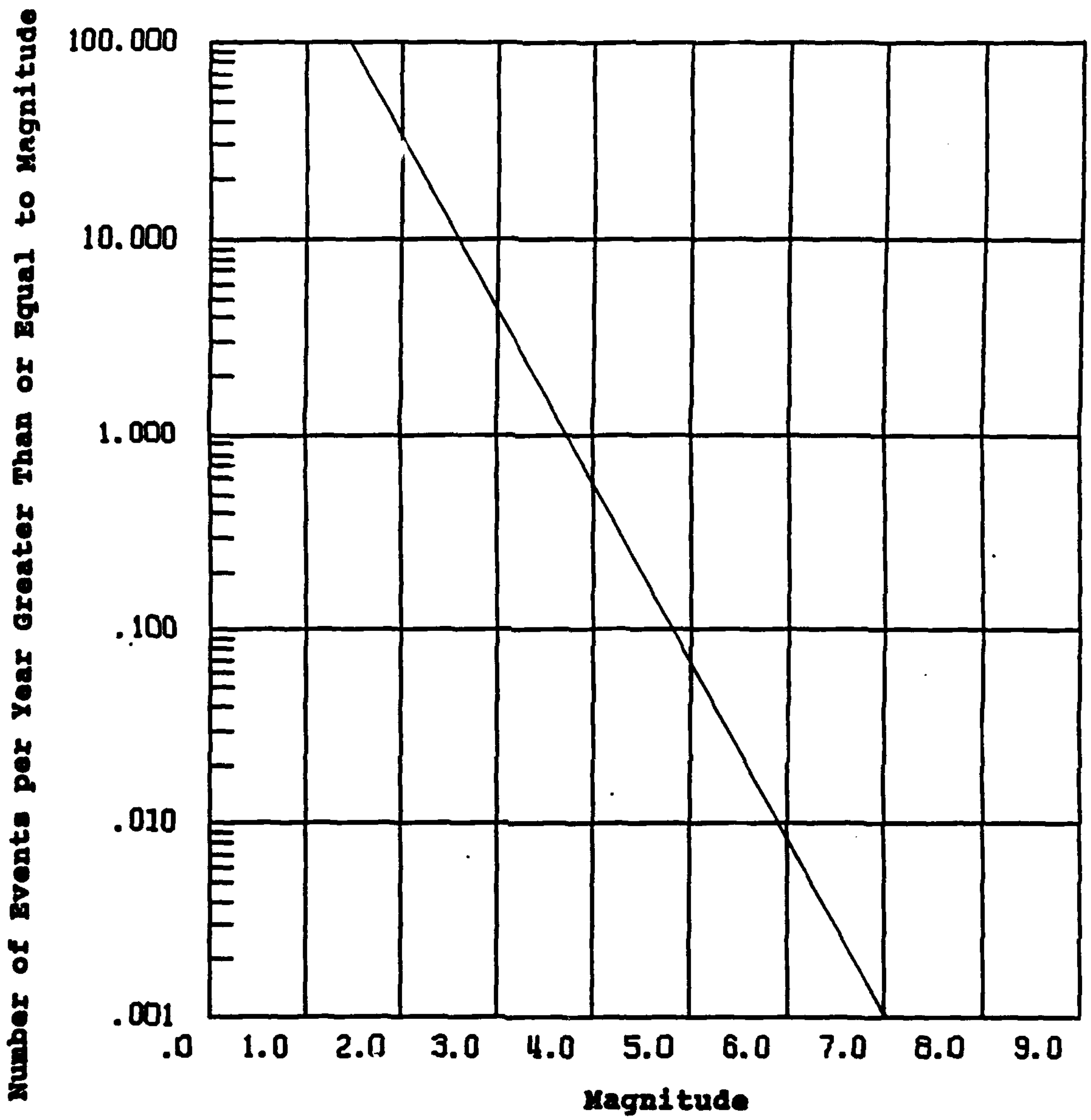
Fault - CAMPROCK

Maximum Magnitude 7

Fault Longitude / Latitude Coordinates

PT1 116.82 , 34.77 PT2 116.7 , 34.68 PT3 116.55 , 34.55

Figure A-8 . Fault recurrence.

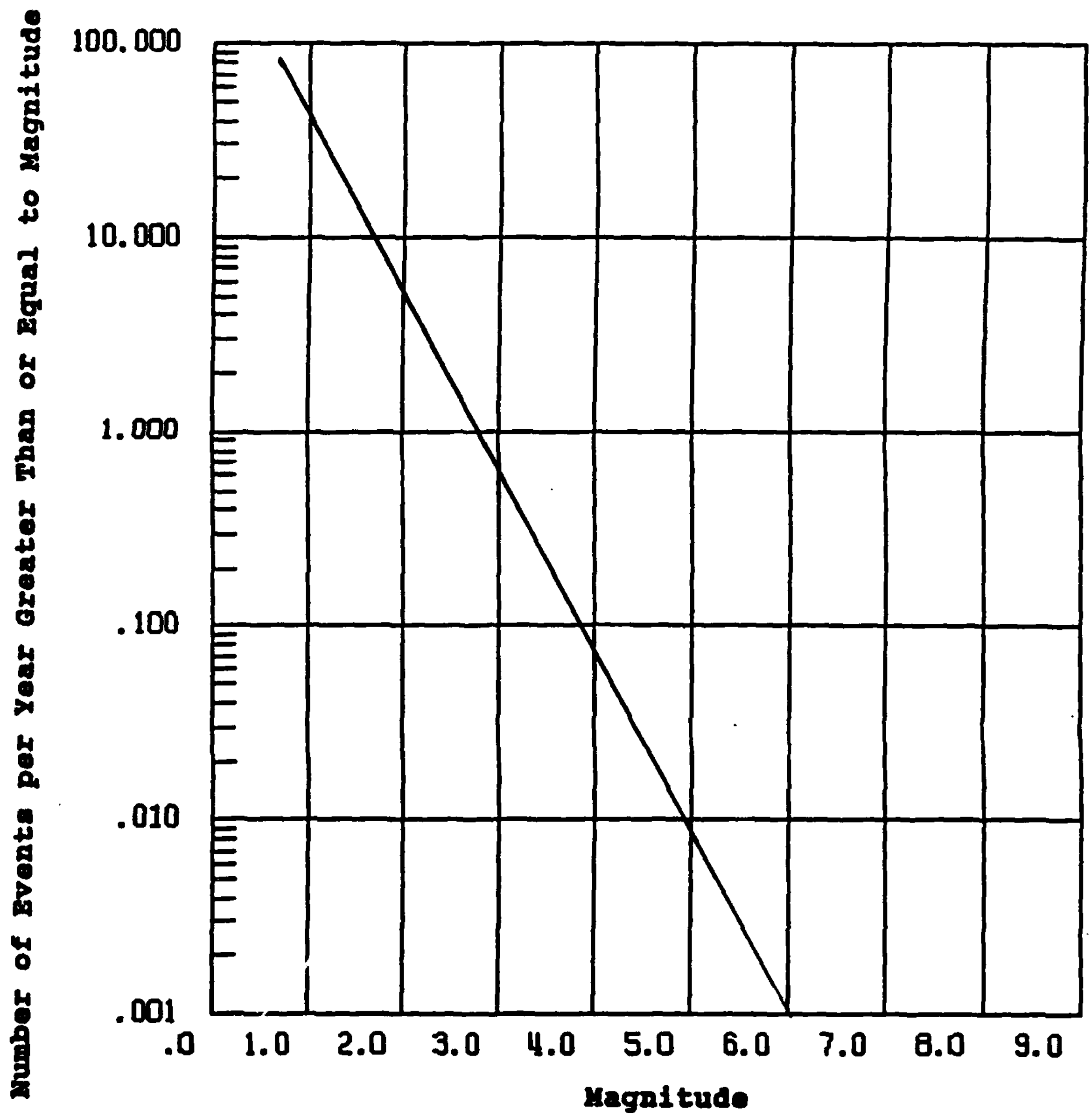


Fault - CALAVERAS

Maximum Magnitude 7.5

Fault Longitude / Latitude Coordinates
PT1 121.3 , 36.75 PT2 121.55 , 37.14 PT3 122 , 37.8

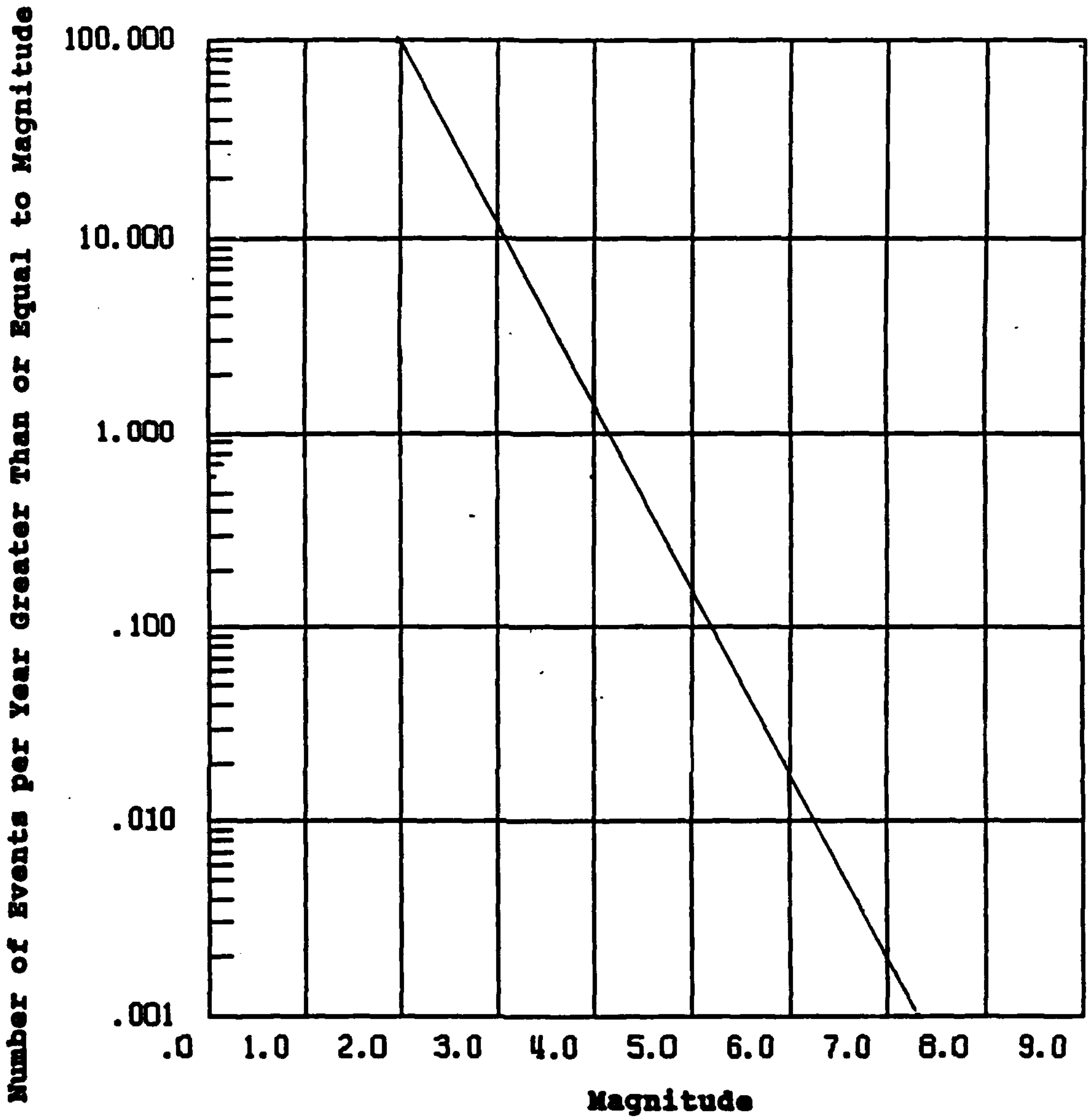
Figure A-9 . Fault recurrence.



Fault - CALICO Maximum Magnitude 7.25

Fault Longitude / Latitude Coordinates
PT1 116.75 , 34.9 PT2 116.52 , 34.65 PT3 116.22 , 34.37

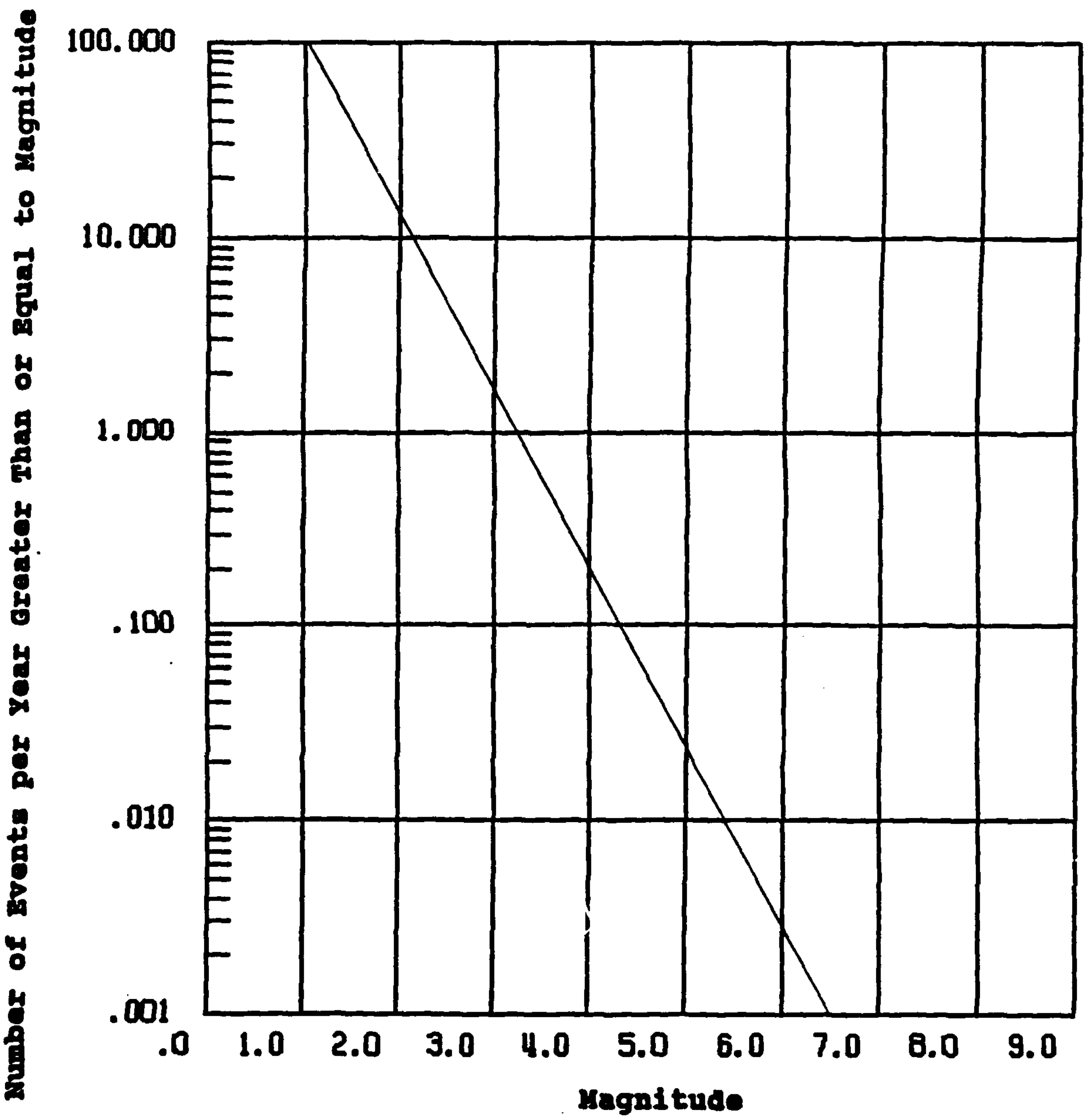
Figure A-10 . Fault recurrence.



Fault - COYOTE CREEK Maximum Magnitude 7

Fault Longitude / Latitude Coordinates
PT1 116.52 , 33.46 PT2 116.27 , 33.26 PT3 115.99 , 33.02

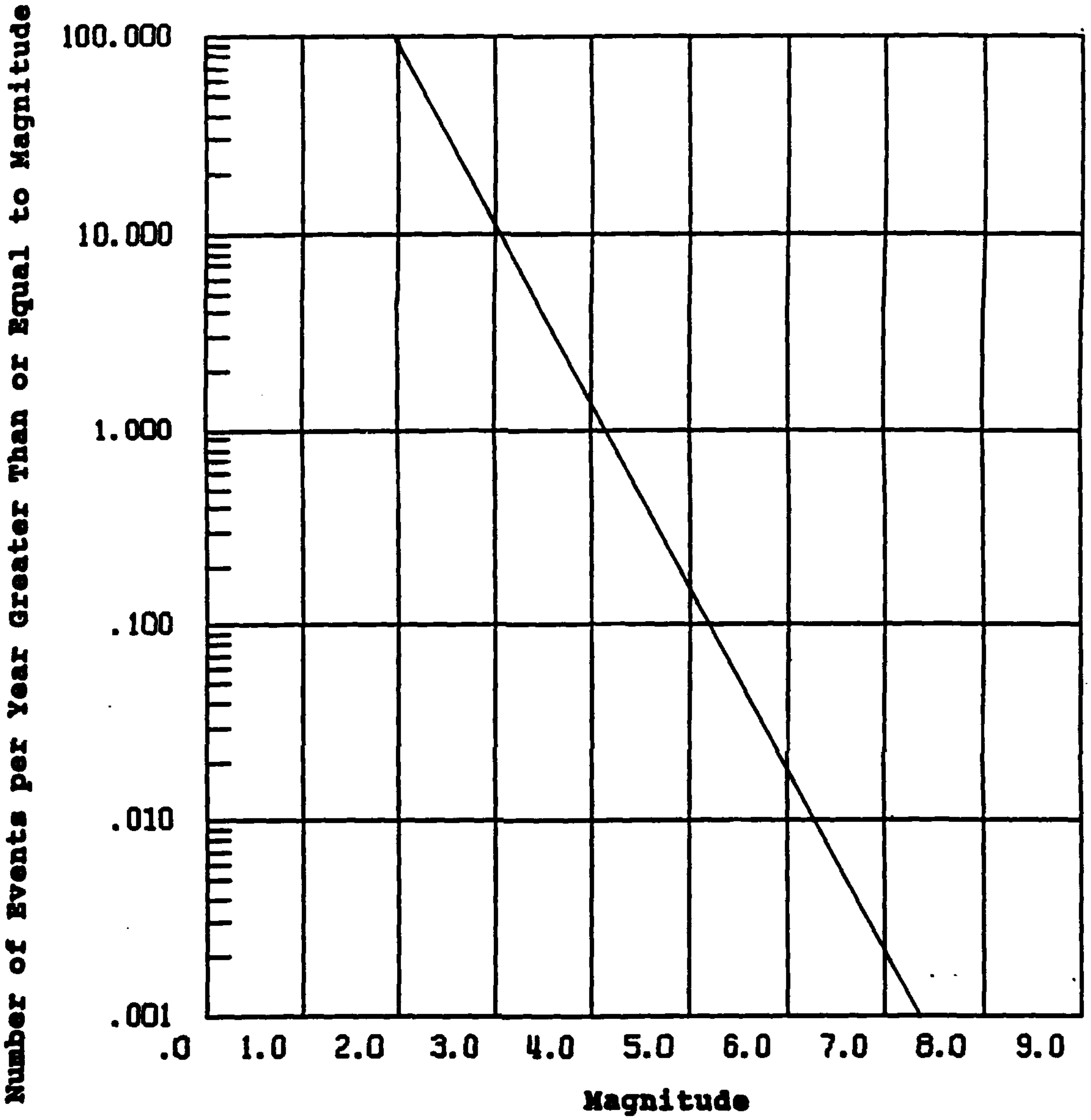
Figure A-11 . Fault recurrence.



Fault - DEATH VALLEY Maximum Magnitude 7

Fault Longitude / Latitude Coordinates
PT1 117 , 36.53 PT2 116.84 , 36 PT3 116.3 , 35.6

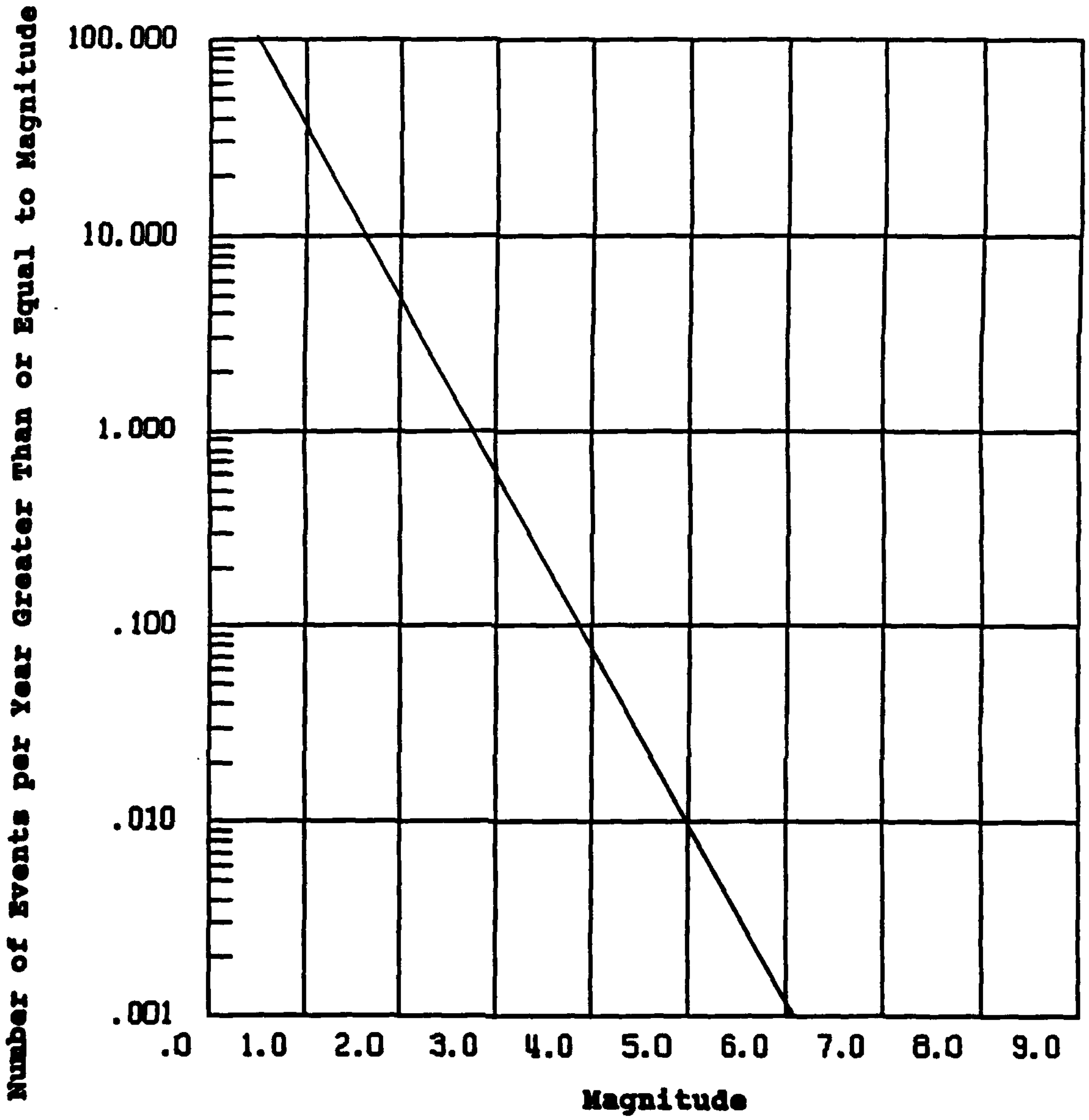
Figure A-12 . Fault recurrence.



Fault - ELSINORE   Maximum Magnitude 7.5

Fault Longitude / Latitude Coordinates
PT1 117.71 , 33.97 PT2 116.82 , 33.25 PT3 116.02 , 32.8

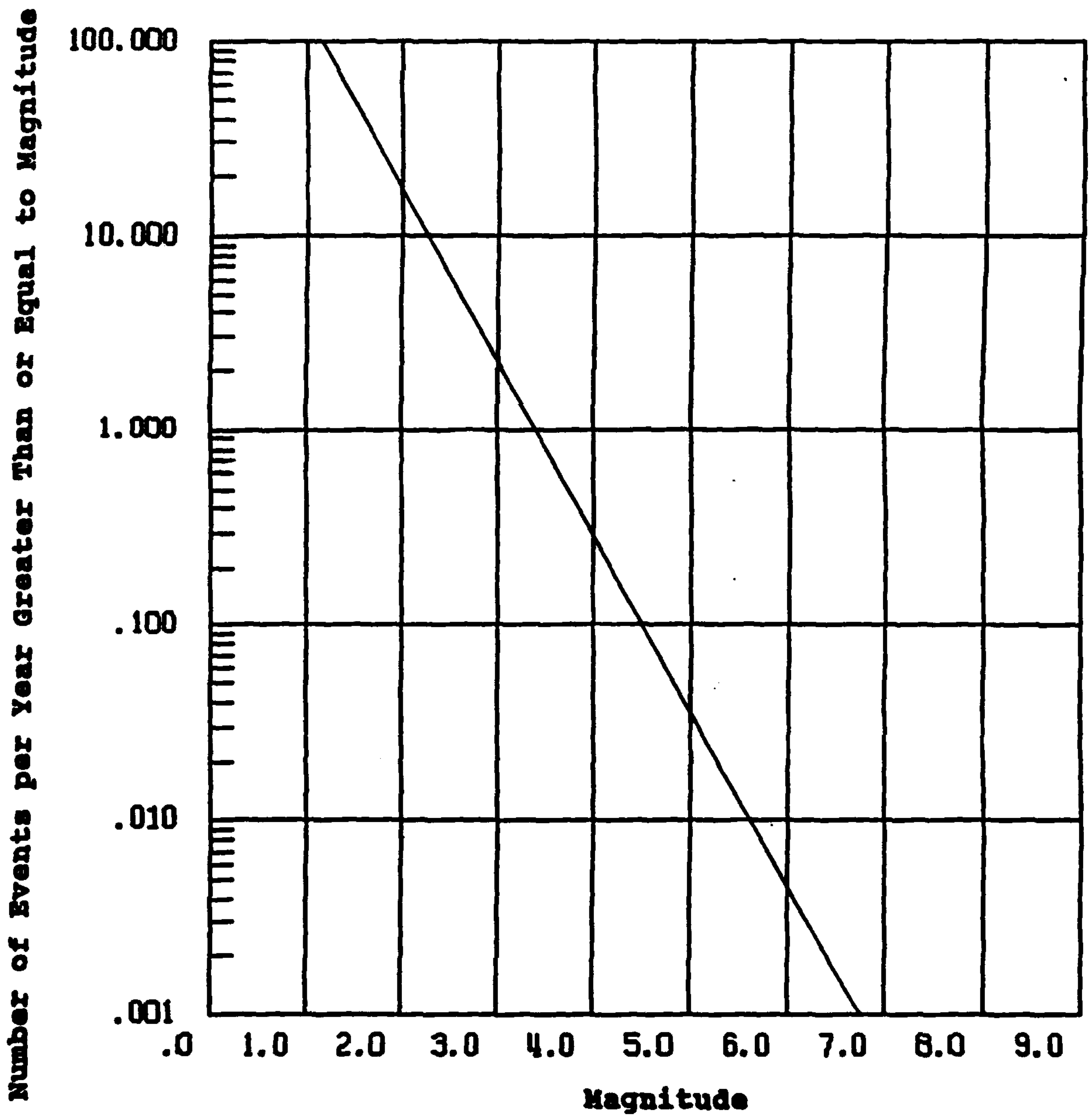
Figure A-13 . Fault recurrence.



Fault - EMERSON Maximum Magnitude 7.2

Fault Longitude / Latitude Coordinates
PT1 116.54 , 34.55 PT2 116.4 , 34.44 PT3 116.26 , 34.28

Figure A-14 . Fault recurrence.



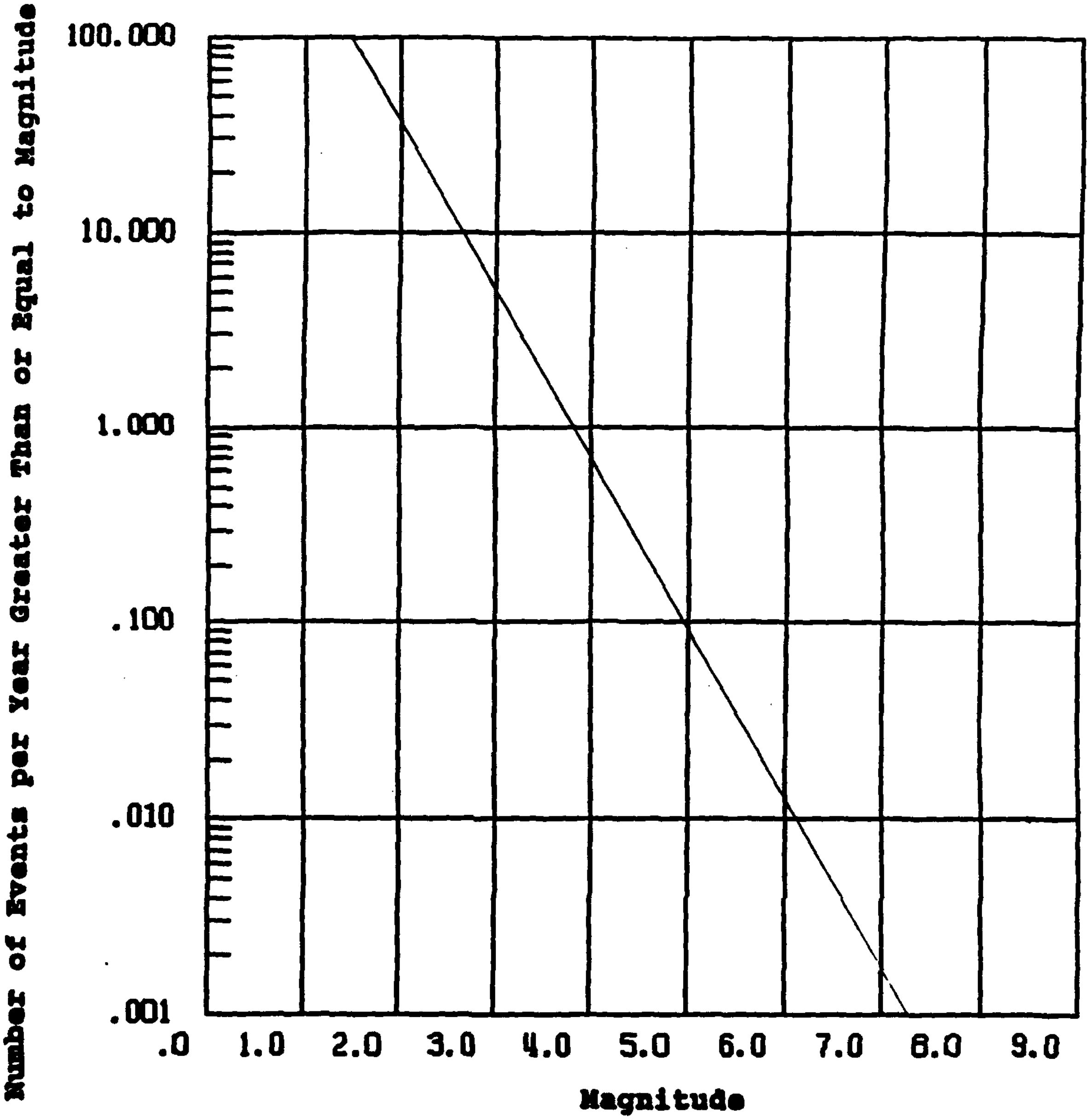
Fault - FURNACE CREEK

Maximum Magnitude 8.25

Fault Longitude / Latitude Coordinates

PT1 118.1 , 37.64 PT2 116.85 , 36.51 PT3 116.73 , 35.98

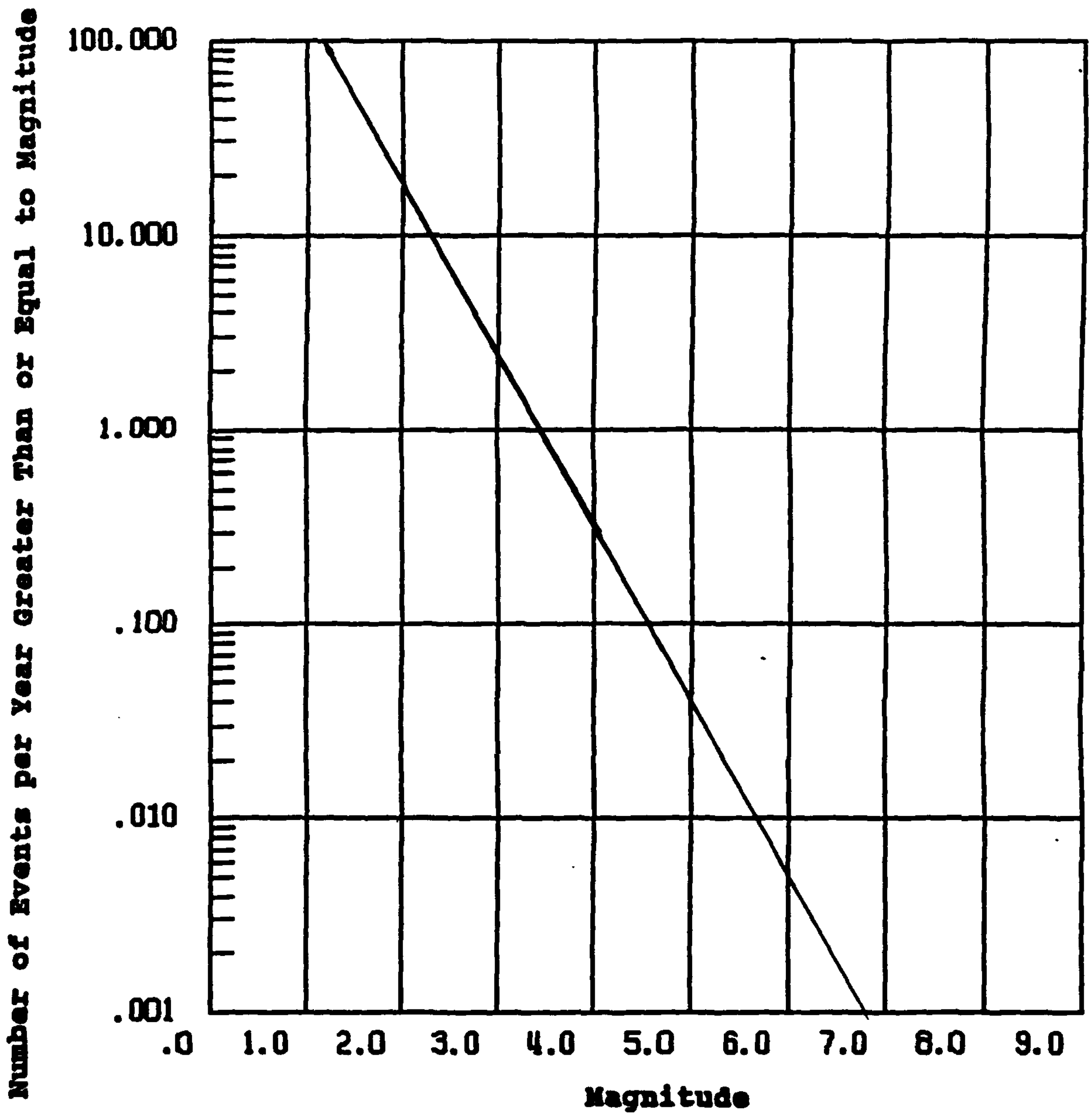
Figure A-15 . Fault recurrence.



Fault - GARLOCK Maximum Magnitude 7.75

Fault Longitude / Latitude Coordinates
PT1 118.9 , 34.73 PT2 117.85 , 35.4 PT3 116.3 , 35.68

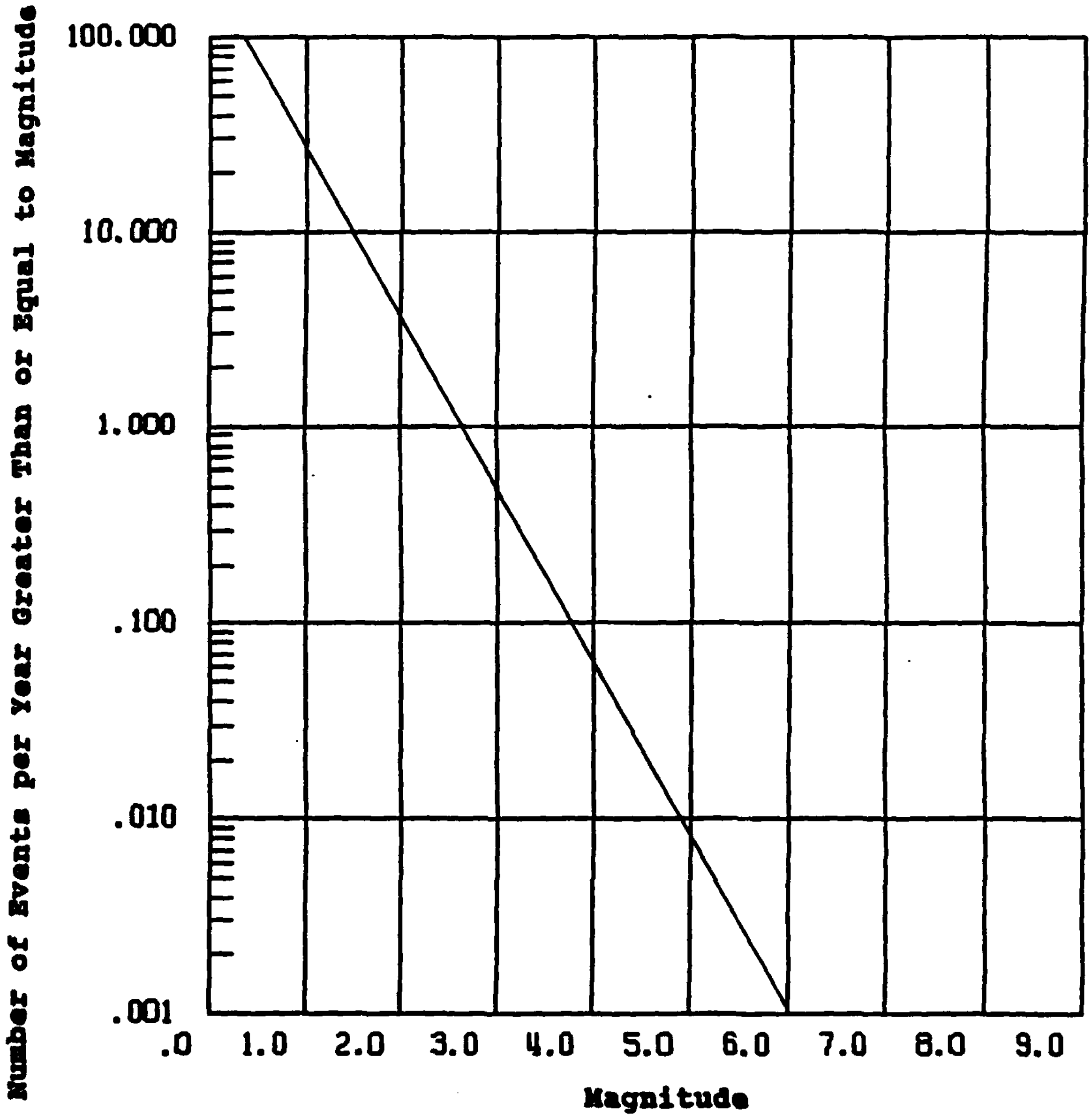
Figure A-16. Fault recurrence.



Fault - GREEN VALLEY & CONCORD Maximum Magnitude 7

Fault Longitude / Latitude Coordinates
PT1 122.19 , 38.35 PT2 122.09 , 38.07 PT3 121.95 , 37.85

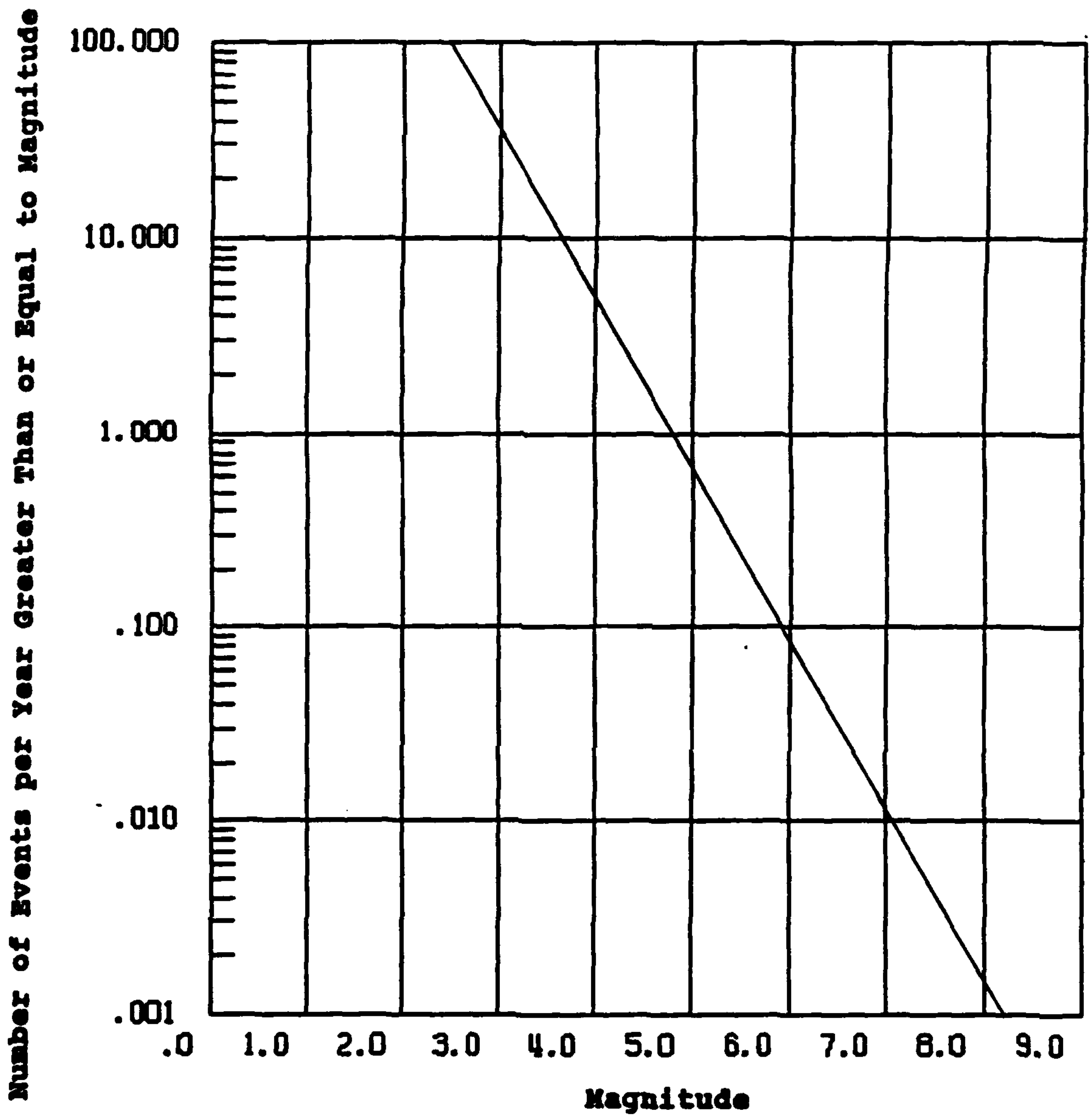
Figure A-17 . Fault recurrence.



Fault - HARPER Maximum Magnitude 7

Fault Longitude / Latitude Coordinates
PT1 117.59 , 35.31 PT2 117.23 , 35.1 PT3 116.92 , 34.9

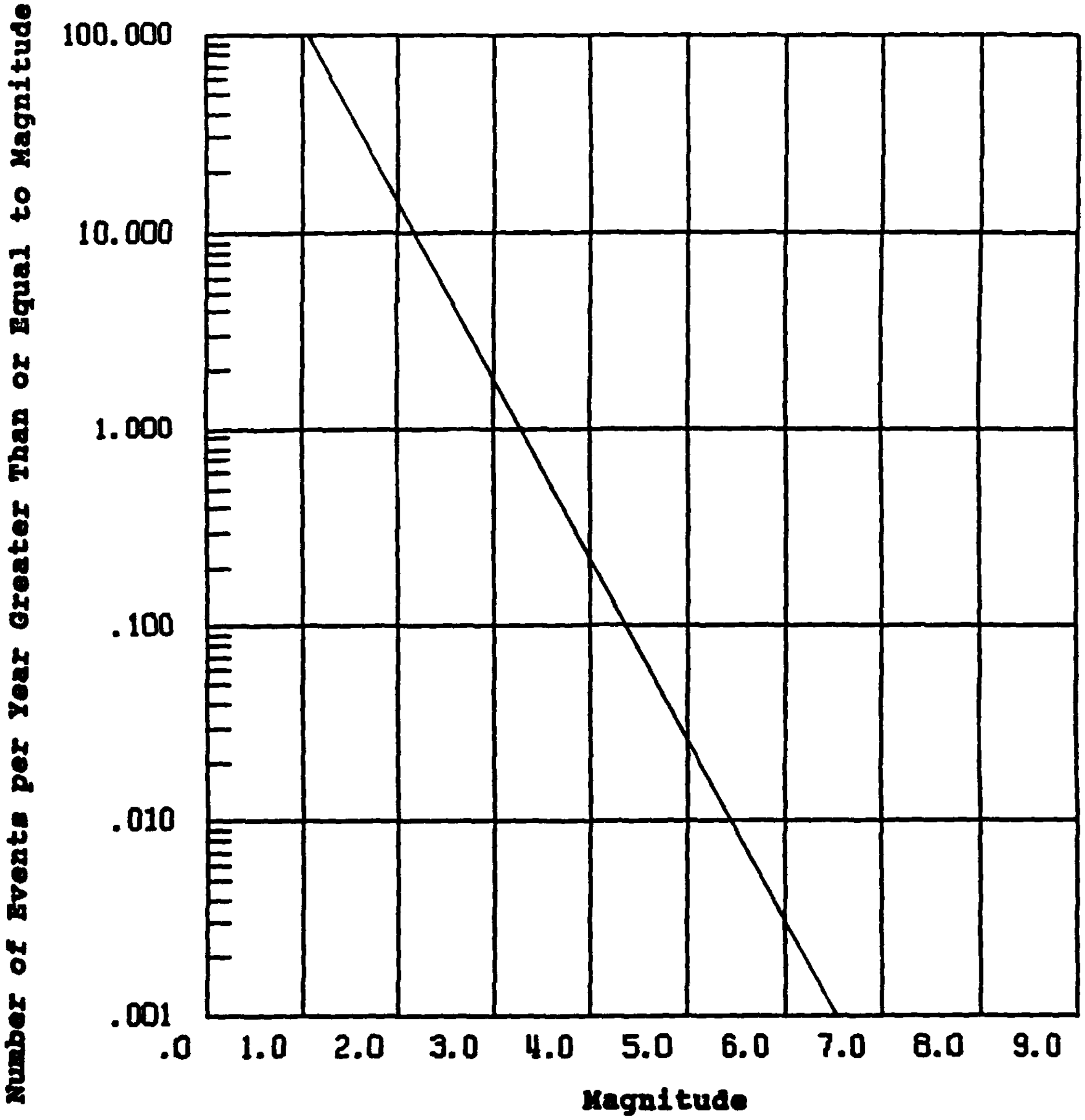
Figure A-18. Fault recurrence.



Fault - HAYWARD Maximum Magnitude 7.5

Fault Longitude / Latitude Coordinates
PT1 122.37 , 38 PT2 122.15 , 37.73 PT3 121.74 , 37.27

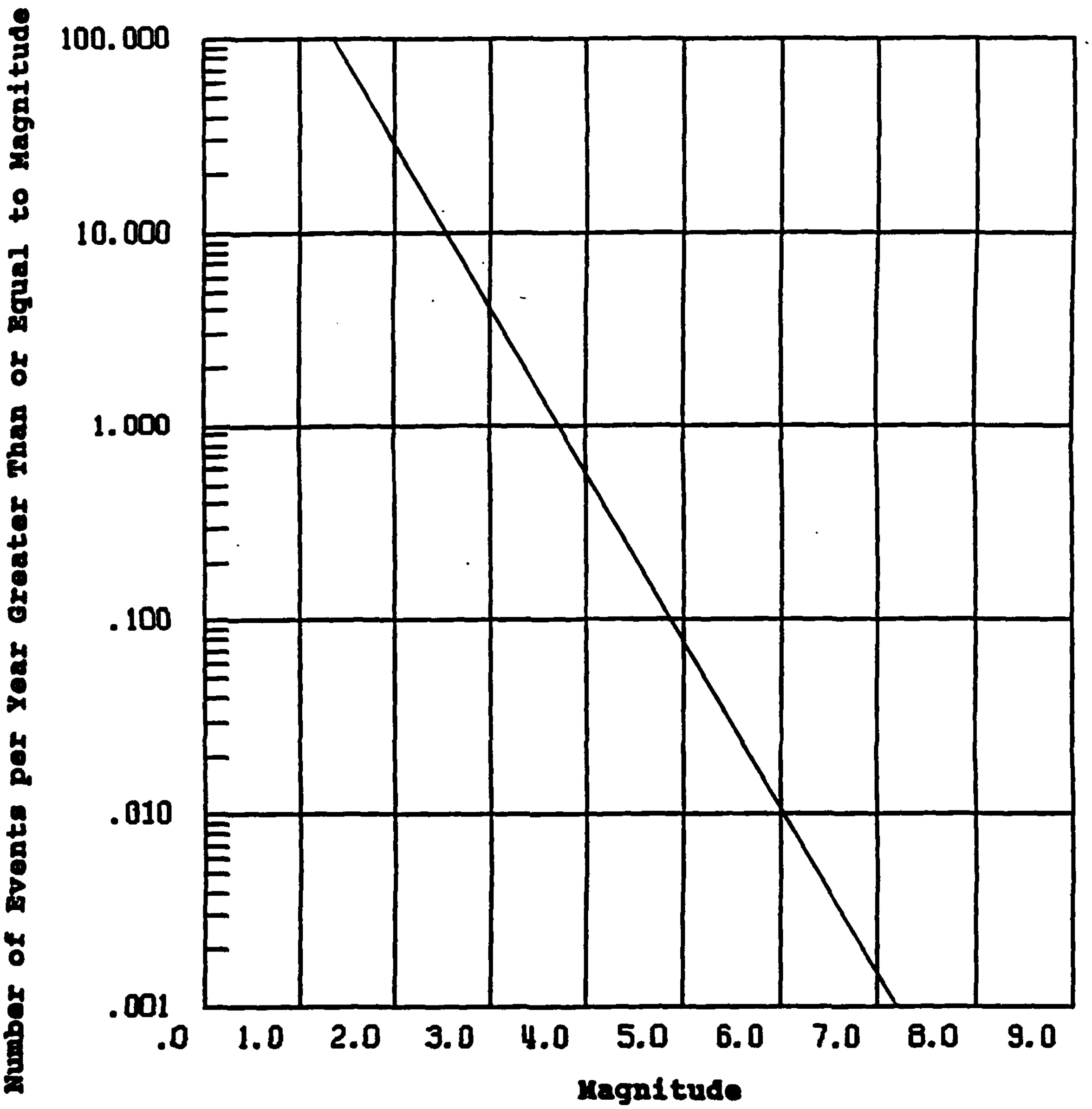
Figure A-19. Fault recurrence.



Fault - HEALDSBURG Maximum Magnitude 6.75

Fault Longitude / Latitude Coordinates
PT1 122.89 , 38.67 PT2 122.64 , 38.37 PT3 122.45 , 38.17

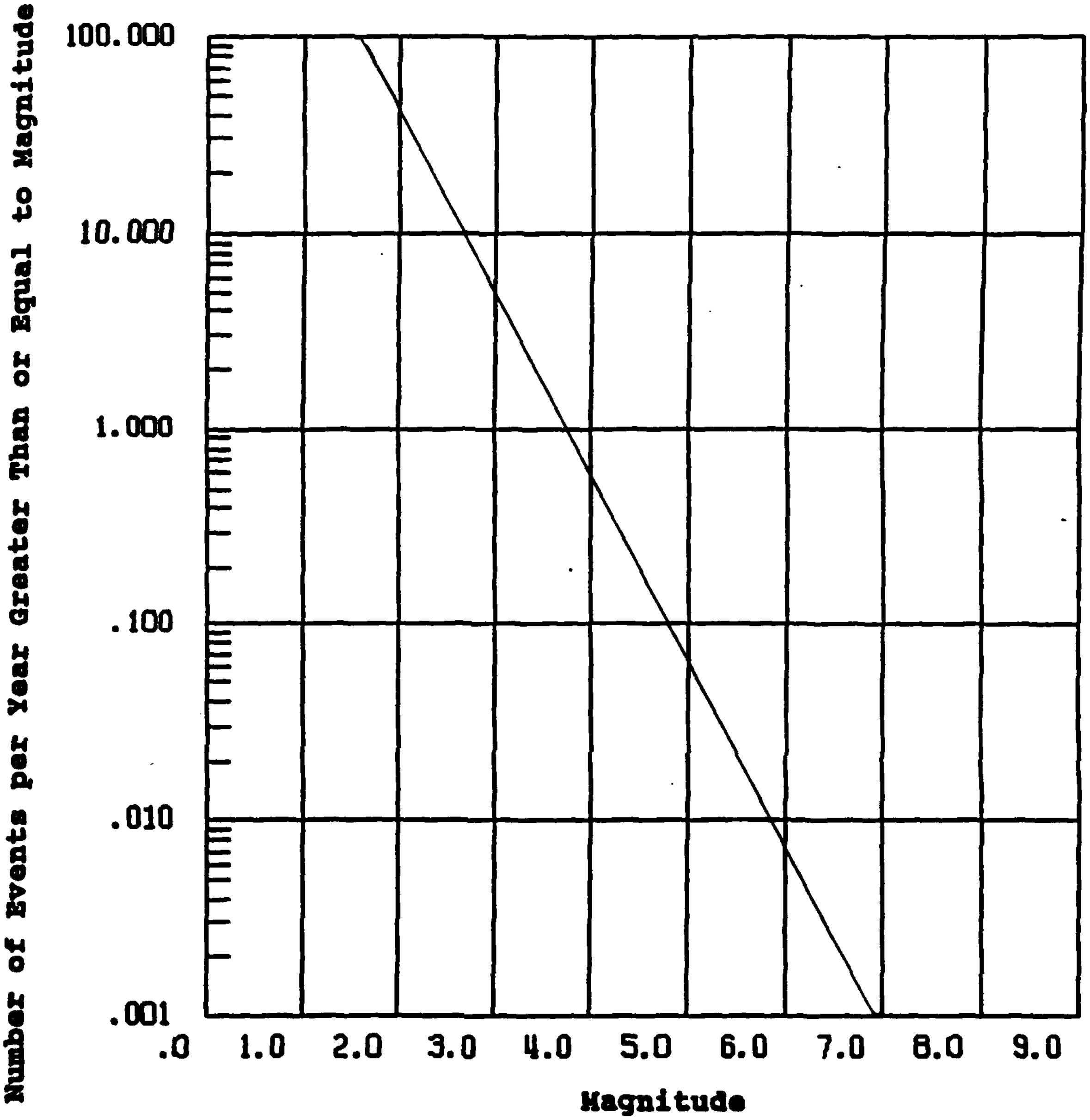
Figure A-20. Fault recurrence.



Fault - HELENDALE **Maximum Magnitude 7.5**

Fault Longitude / Latitude Coordinates
PT1 117.4 , 34.85 PT2 117.06 , 34.55 PT3 116.73 , 34.25

Figure A-21. Fault recurrence.

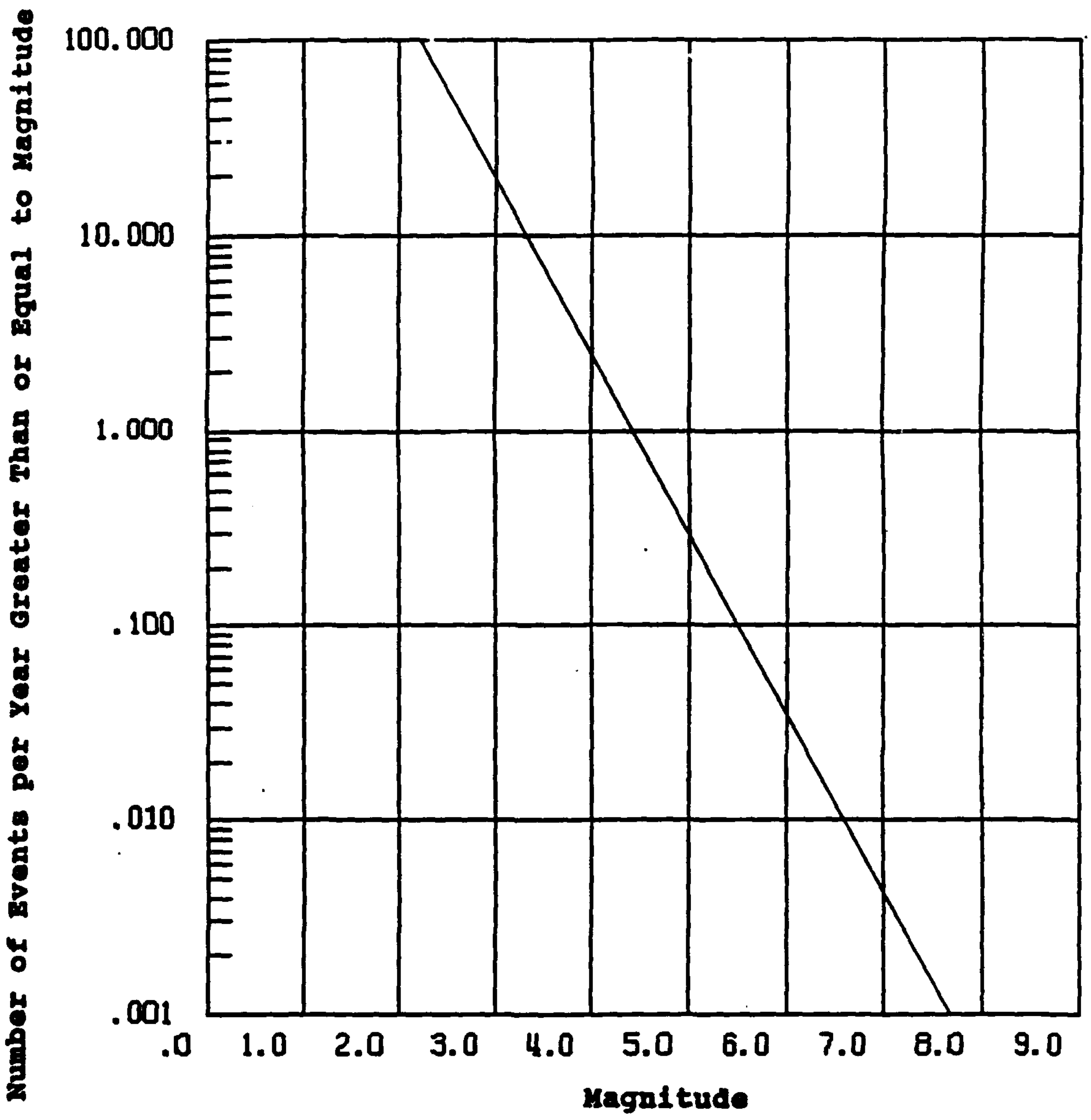


Fault - HOSGRI

Maximum Magnitude 7

Fault Longitude / Latitude Coordinates
PT1 121.5 , 35.9 PT2 121.1 , 35.5 PT3 120.75 , 34.9

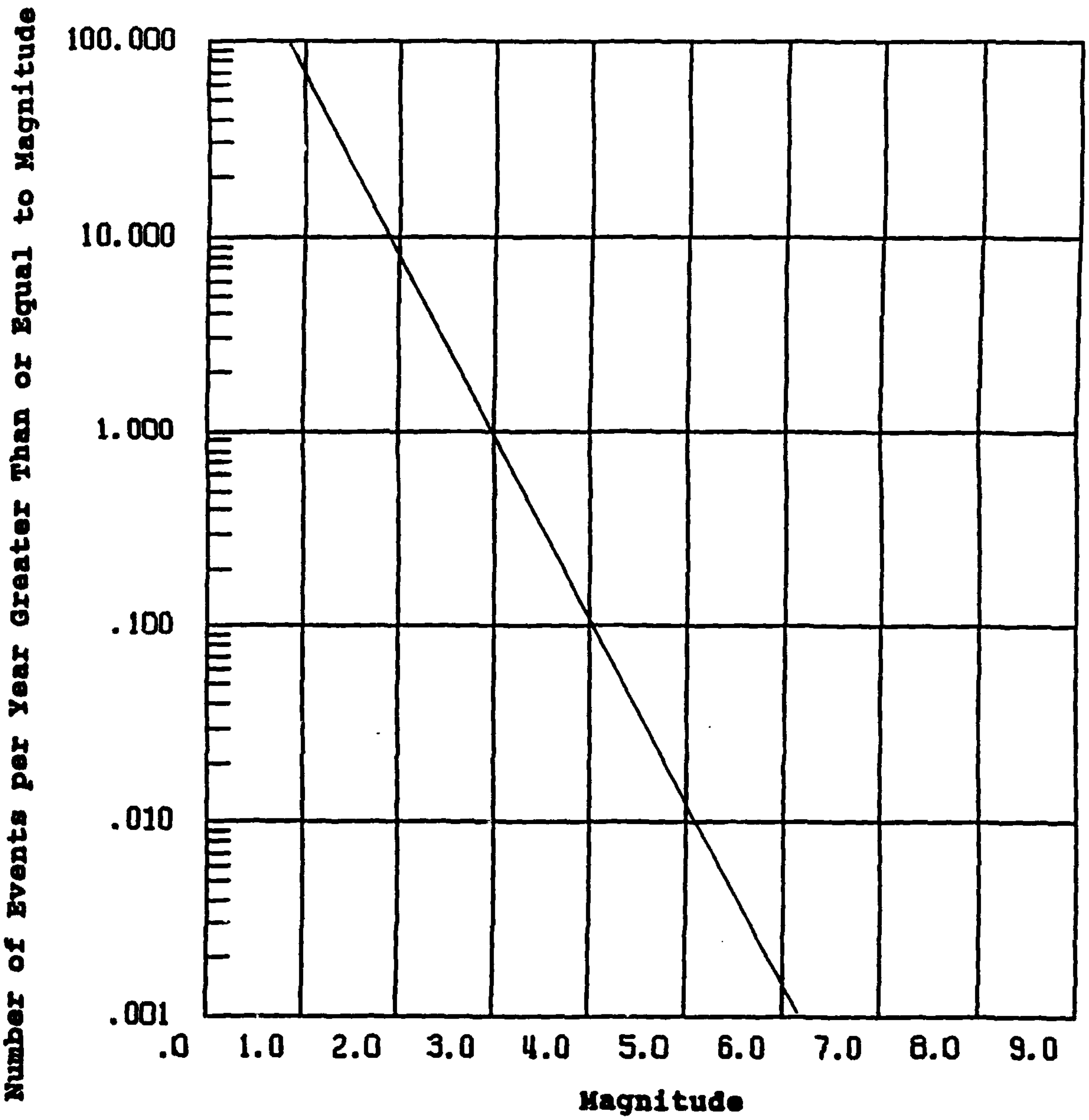
Figure A-22. Fault recurrence.



Fault - IMPERIAL Maximum Magnitude 7

Fault Longitude / Latitude Coordinates
PT1 115.57 , 32.95 PT2 115.4 , 32.72 PT3 115.32 , 32.62

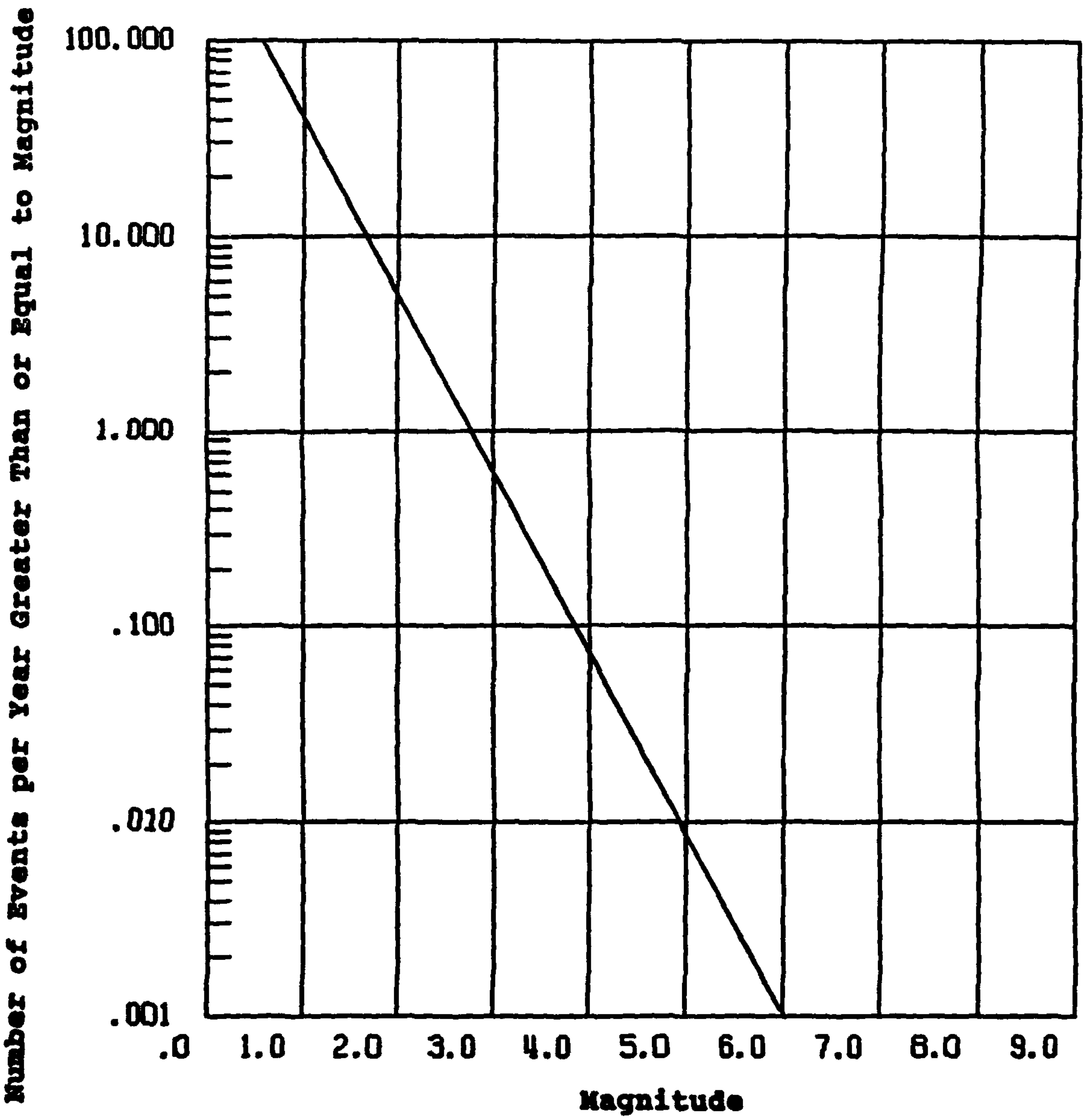
Figure A-23. Fault recurrence.



Fault - INYO MOUNTAIN Maximum Magnitude 7.5

Fault Longitude / Latitude Coordinates
PT1 117.95 , 36.92 PT2 117.81 , 36.66 PT3 117.11 , 36.2

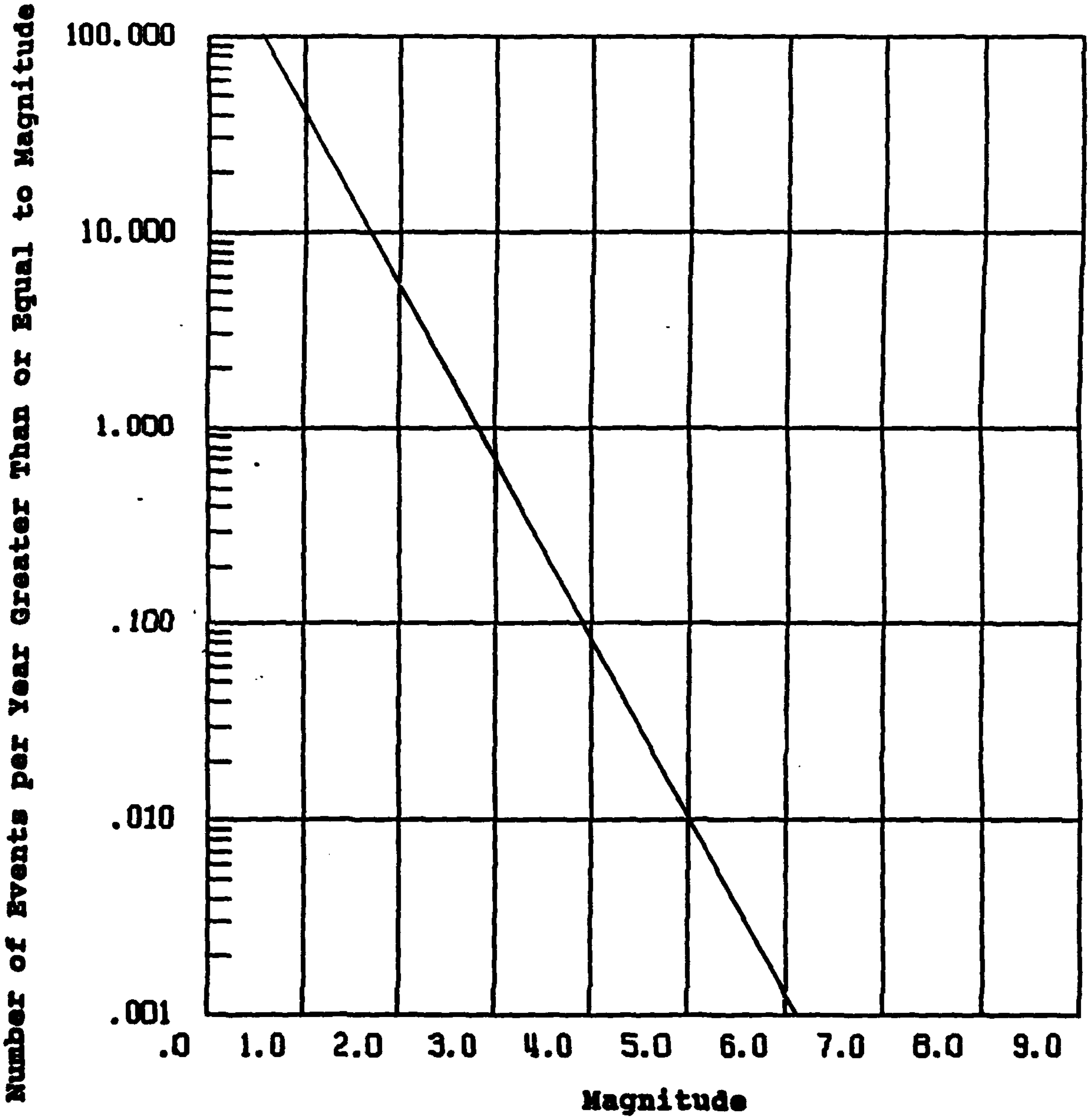
Figure A-24. Fault recurrence.



Fault - LENWOOD Maximum Magnitude 7.25

Fault Longitude / Latitude Coordinates
PT1 117.1 , 34.88 PT2 116.85 , 34.65 PT3 116.5 , 34.3

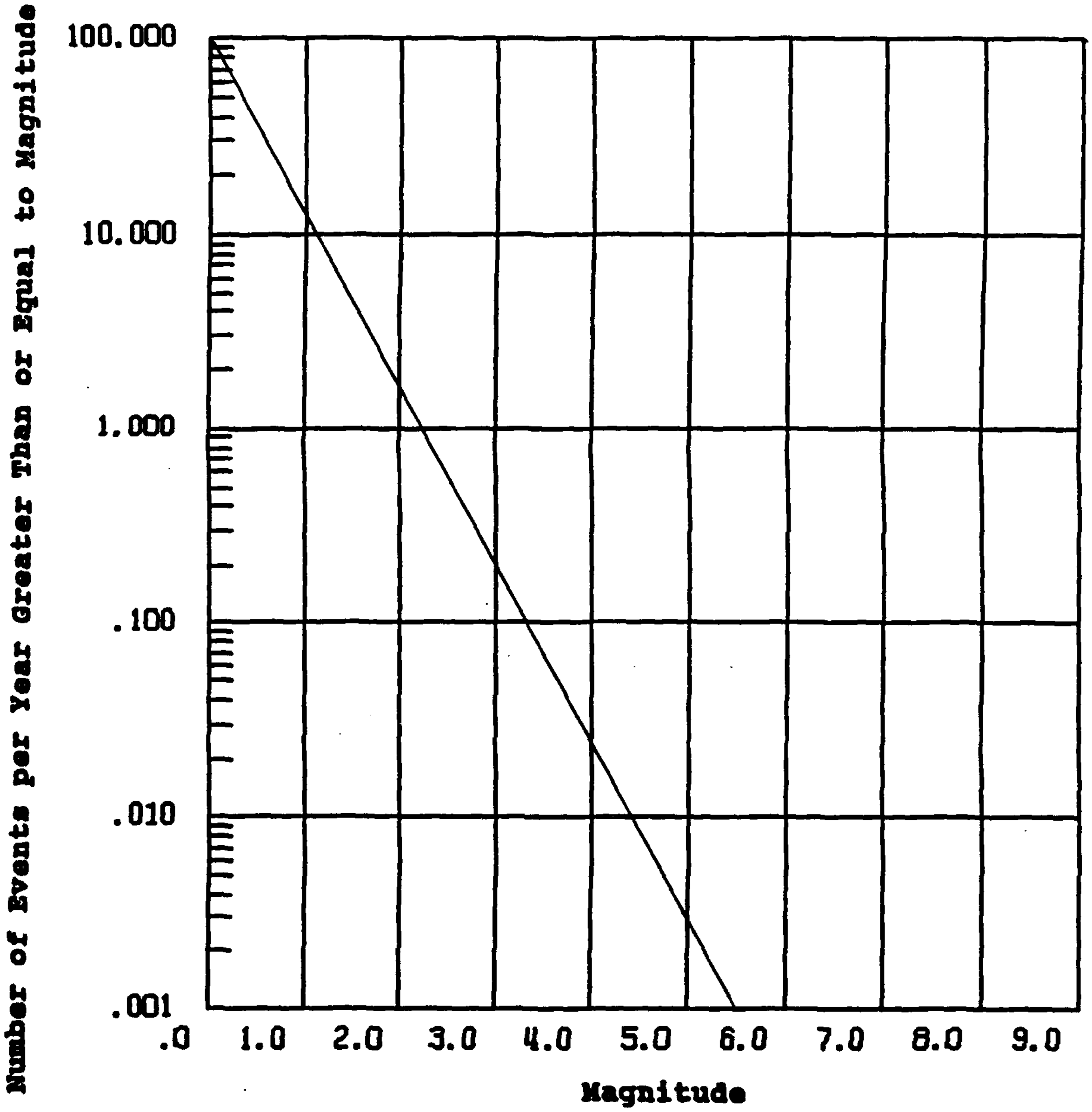
Figure A-25. Fault recurrence.



Fault - LIKELY FAULT Maximum Magnitude 7.5

Fault Longitude / Latitude Coordinates
PT1 121 , 41.56 PT2 120.64 , 41.25 PT3 120.27 , 40.9

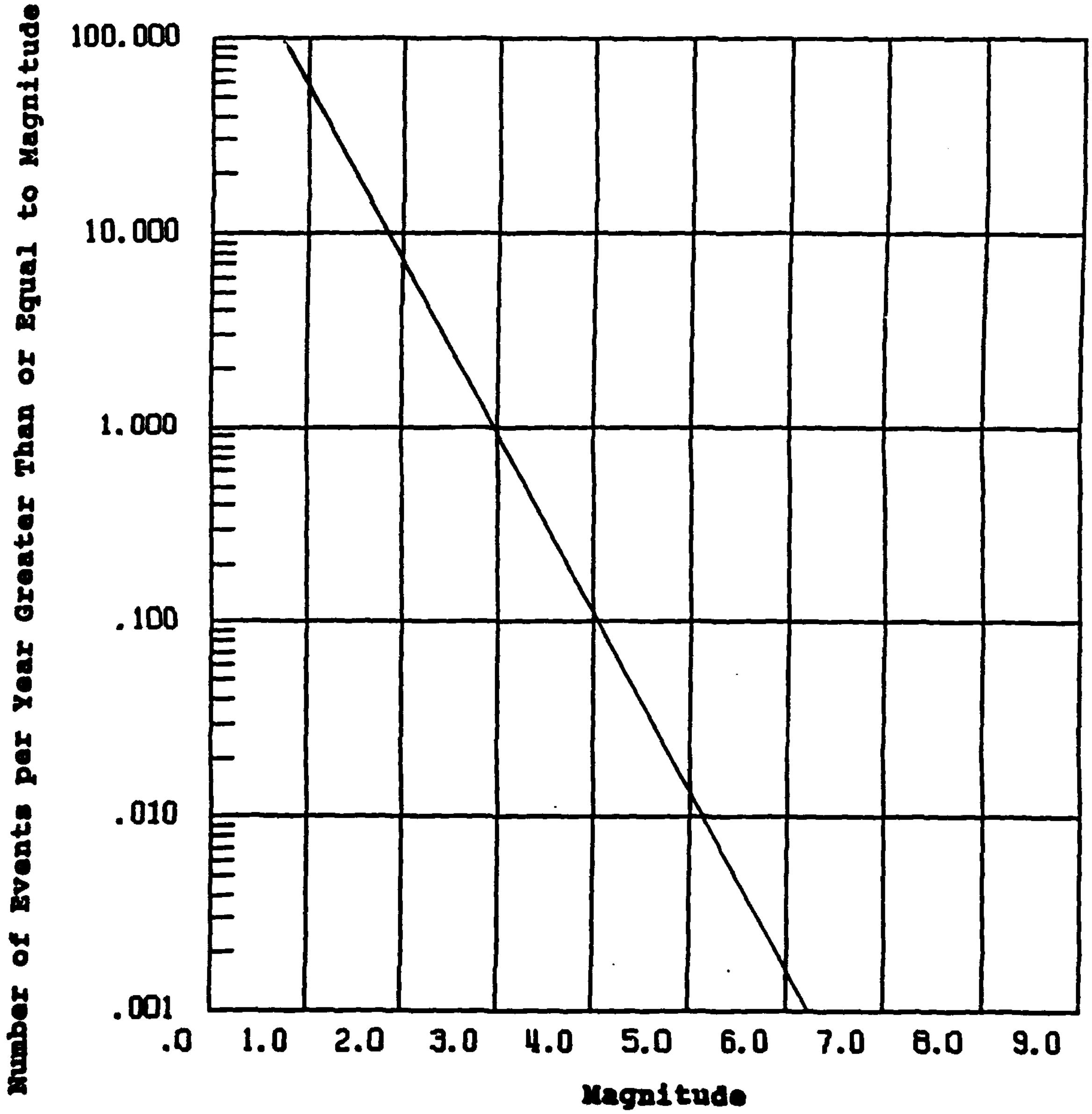
Figure A-26. Fault recurrence.



Fault - LOCKHART Maximum Magnitude 7.5

Fault Longitude / Latitude Coordinates
PT1 117.76 , 35.21 PT2 117.39 , 35.02 PT3 117.1 , 34.88

Figure A-27. Fault recurrence.



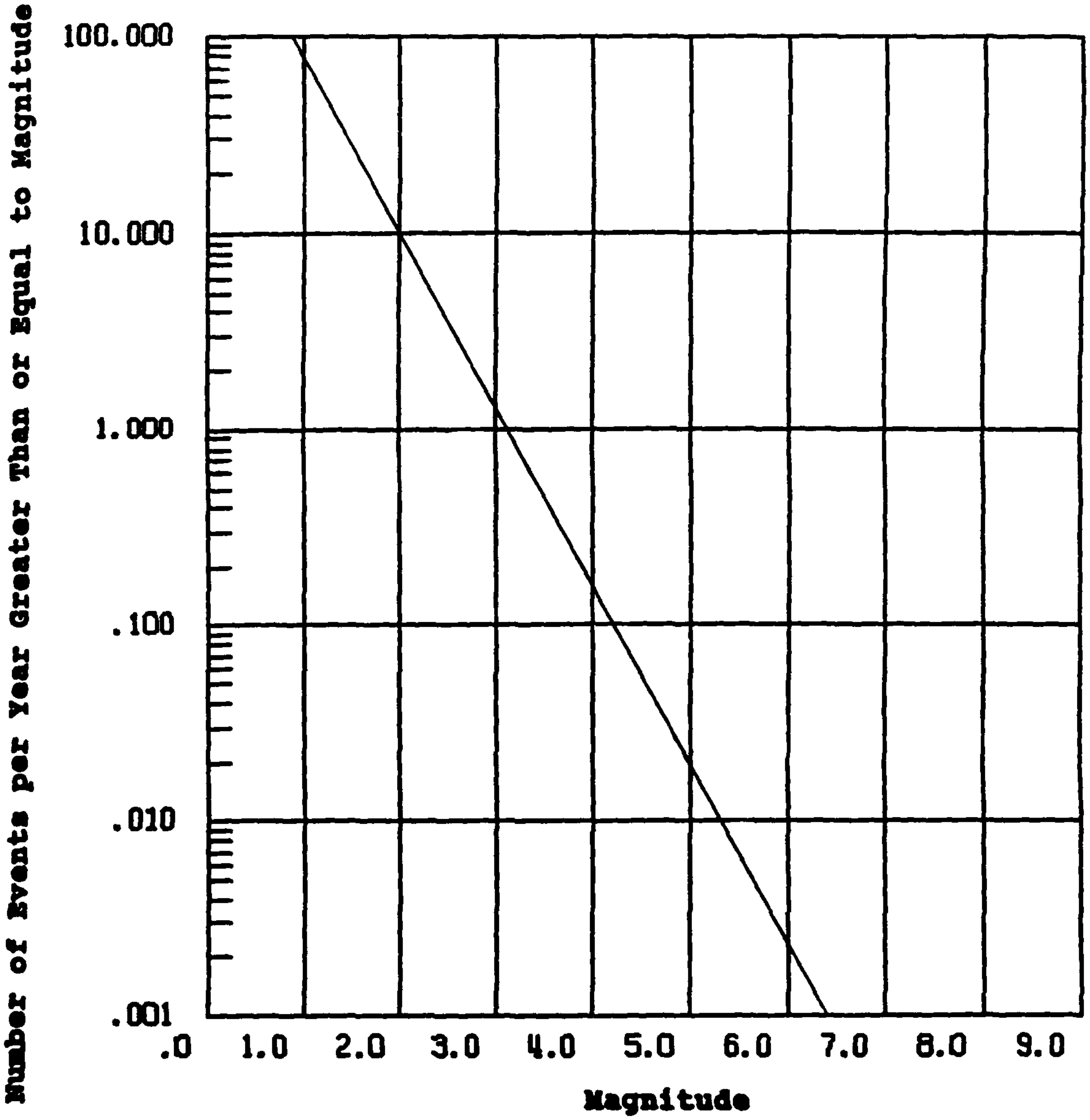
Fault - LUDLOW

Maximum Magnitude 7.25

Fault Longitude / Latitude Coordinates

PT1 116.23 , 34.95 PT2 116.1 , 34.65 PT3 115.85 , 34.45

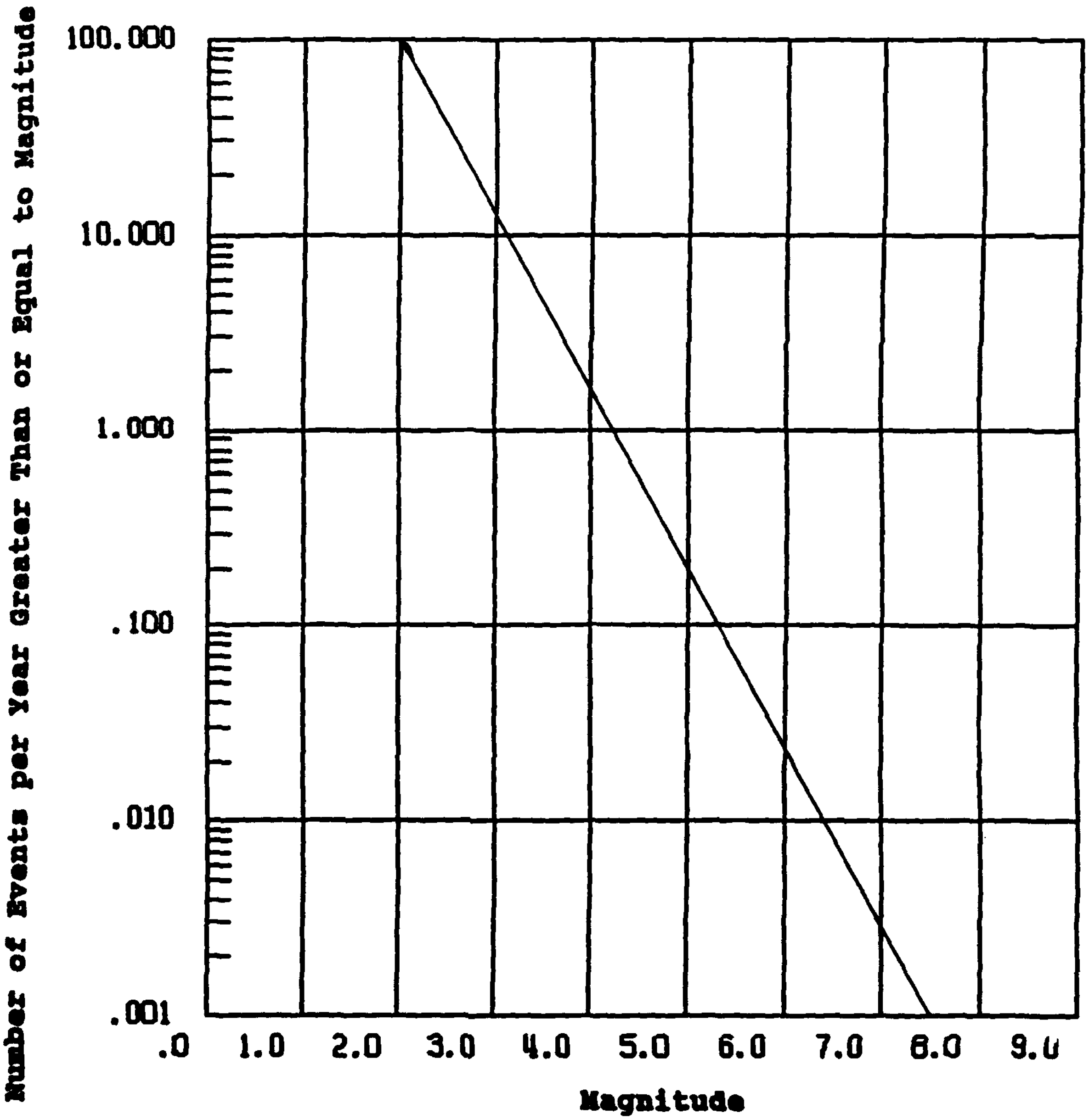
Figure A-28. Fault recurrence.



Fault - MALIBU RAYMOND Maximum Magnitude 7.5

Fault Longitude / Latitude Coordinates
PT1 118.94 , 34.04 PT2 118.45 , 34.04 PT3 117.45 , 34.18

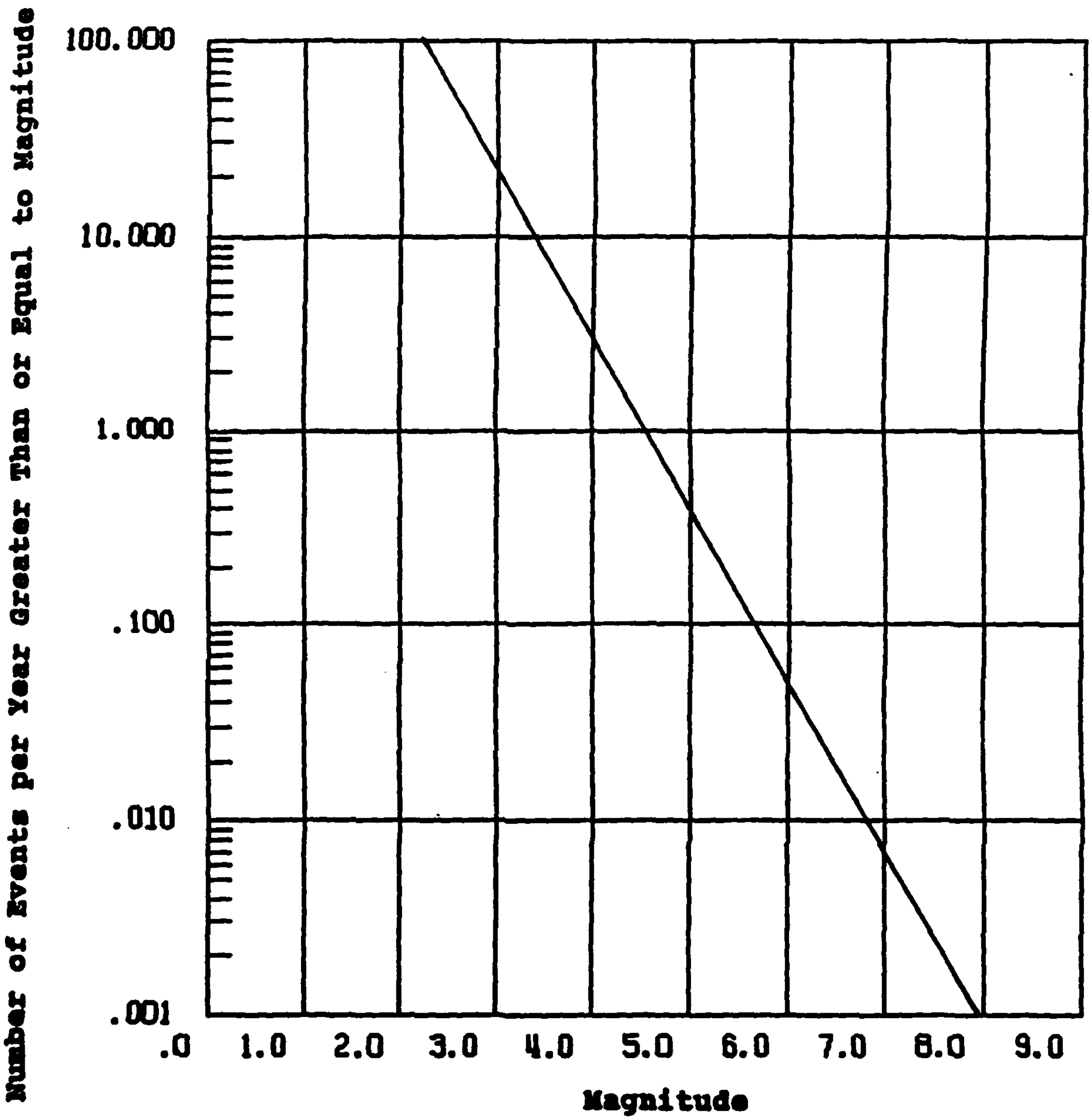
Figure A-29. Fault recurrence.



Fault - MENDOCINO Maximum Magnitude 7.5

Fault Longitude / Latitude Coordinates
PT1 124.45 , 40.35 PT2 124.9 , 40.35 PT3 I25.32 , 40.4

Figure A-30. Fault recurrence.



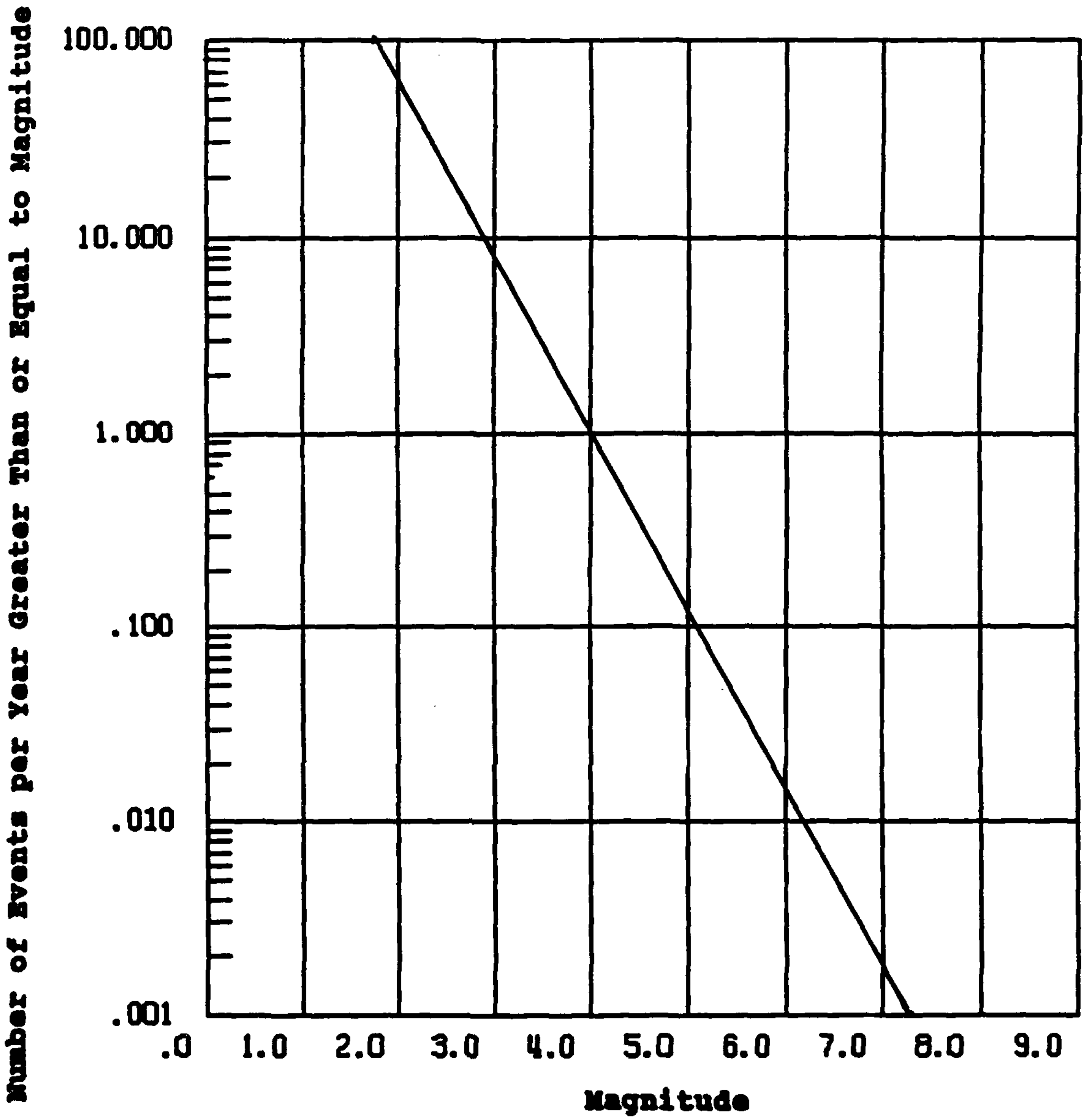
Fault - MONO LAKE & HILTON

Maximum Magnitude 6.75

Fault Longitude / Latitude Coordinates

PT1 119.2 , 38.16 PT2 119 , 37.73 PT3 118.56 , 37.25

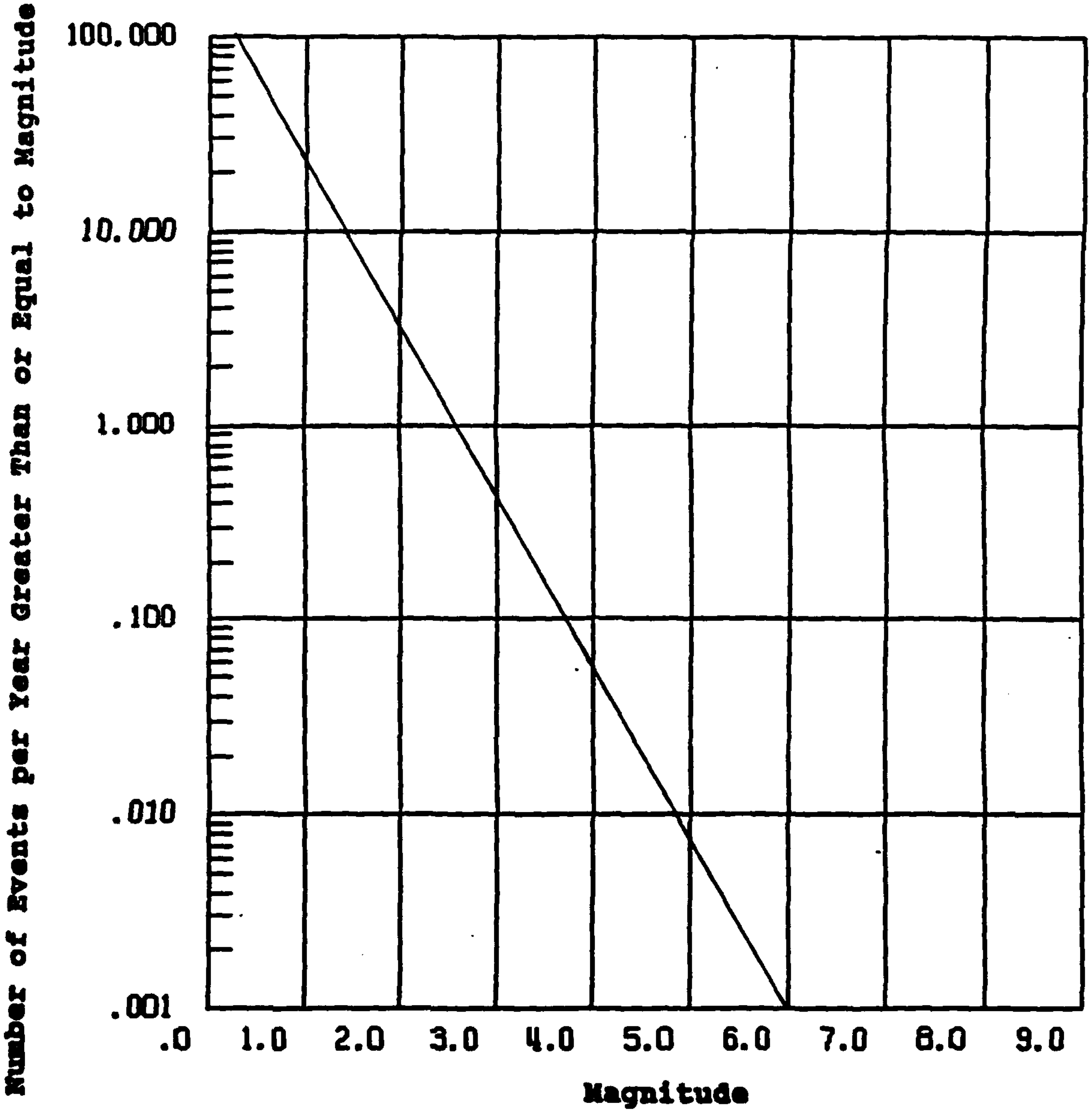
Figure A-31. Fault recurrence.



Fault - NEWPORT-INGLEWOOD Maximum Magnitude 7

Fault Longitude / Latitude Coordinates
PT1 118.38 , 34.02 PT2 118.18 , 33.8 PT3 117.93 , 33.62

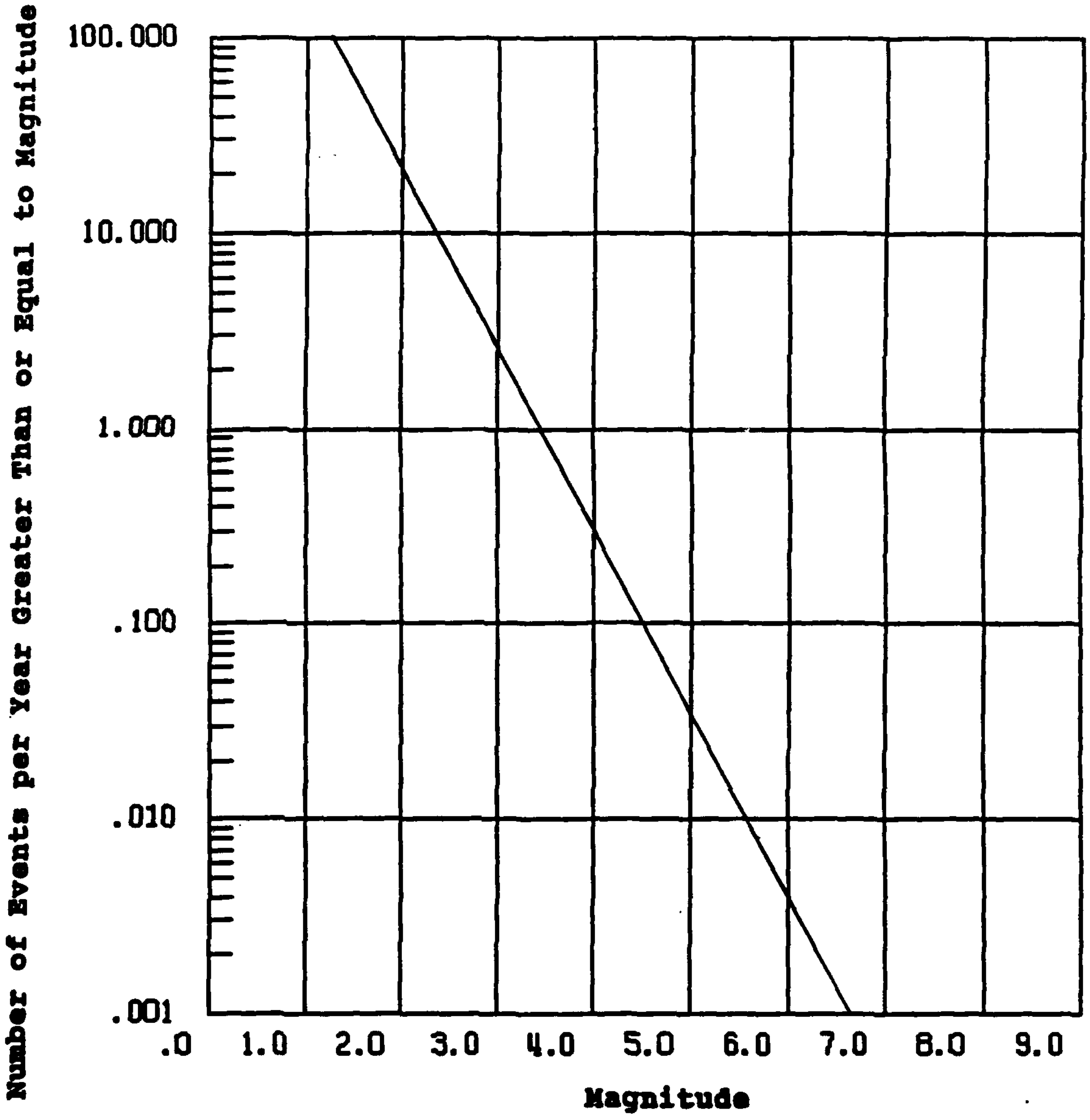
Figure A-32. Fault recurrence.



Fault - OAKRIDGE **Maximum Magnitude 7.5**

Fault Longitude / Latitude Coordinates
PT1 119.24 , 34.23 PT2 119.05 , 34.35 PT3 118.85 , 34.38

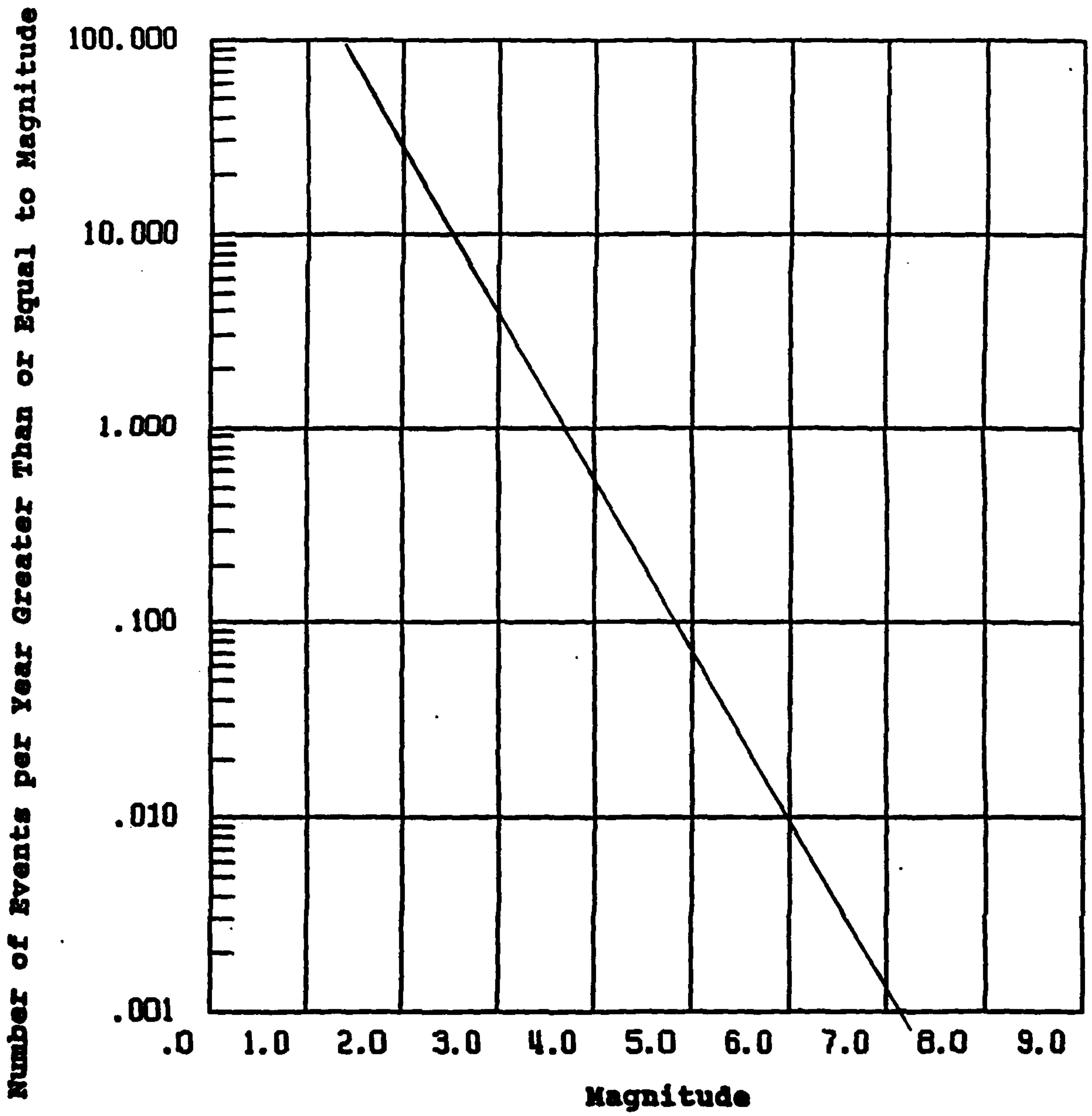
Figure A-33. Fault recurrence.



Fault - ORTIGALITO Maximum Magnitude 7.5

Fault Longitude / Latitude Coordinates
PT1 121.34 , 37.43 PT2 121.1 , 37.03 PT3 120.84 , 36.67

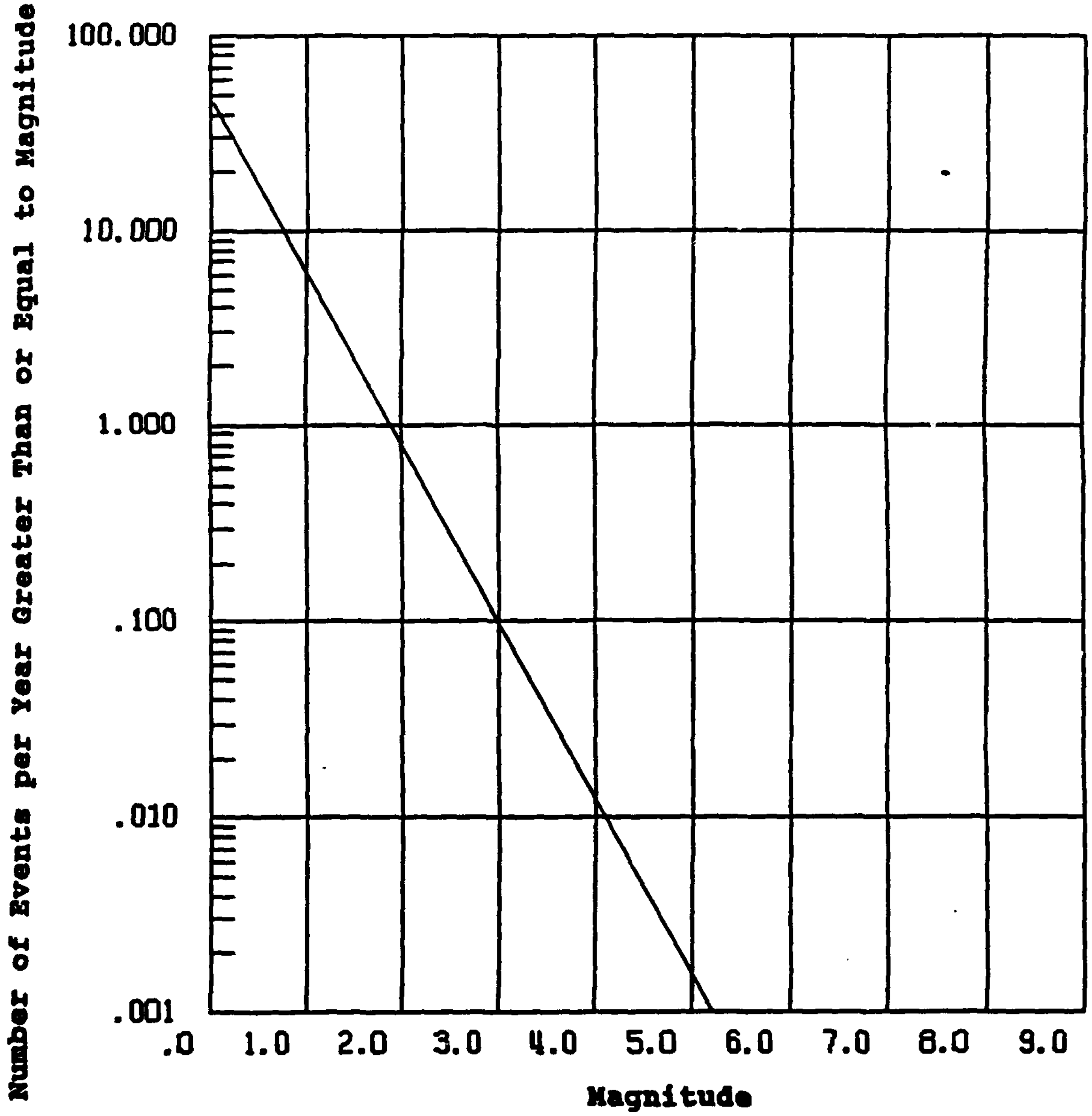
Figure A-34. Fault recurrence.



Fault - OWENS VALLEY Maximum Magnitude 8.25

Fault Longitude / Latitude Coordinates
PT1 118 , 36.23 PT2 118.25 , 37.06 PT3 118.36 , 37.6

Figure A-35. Fault recurrence.

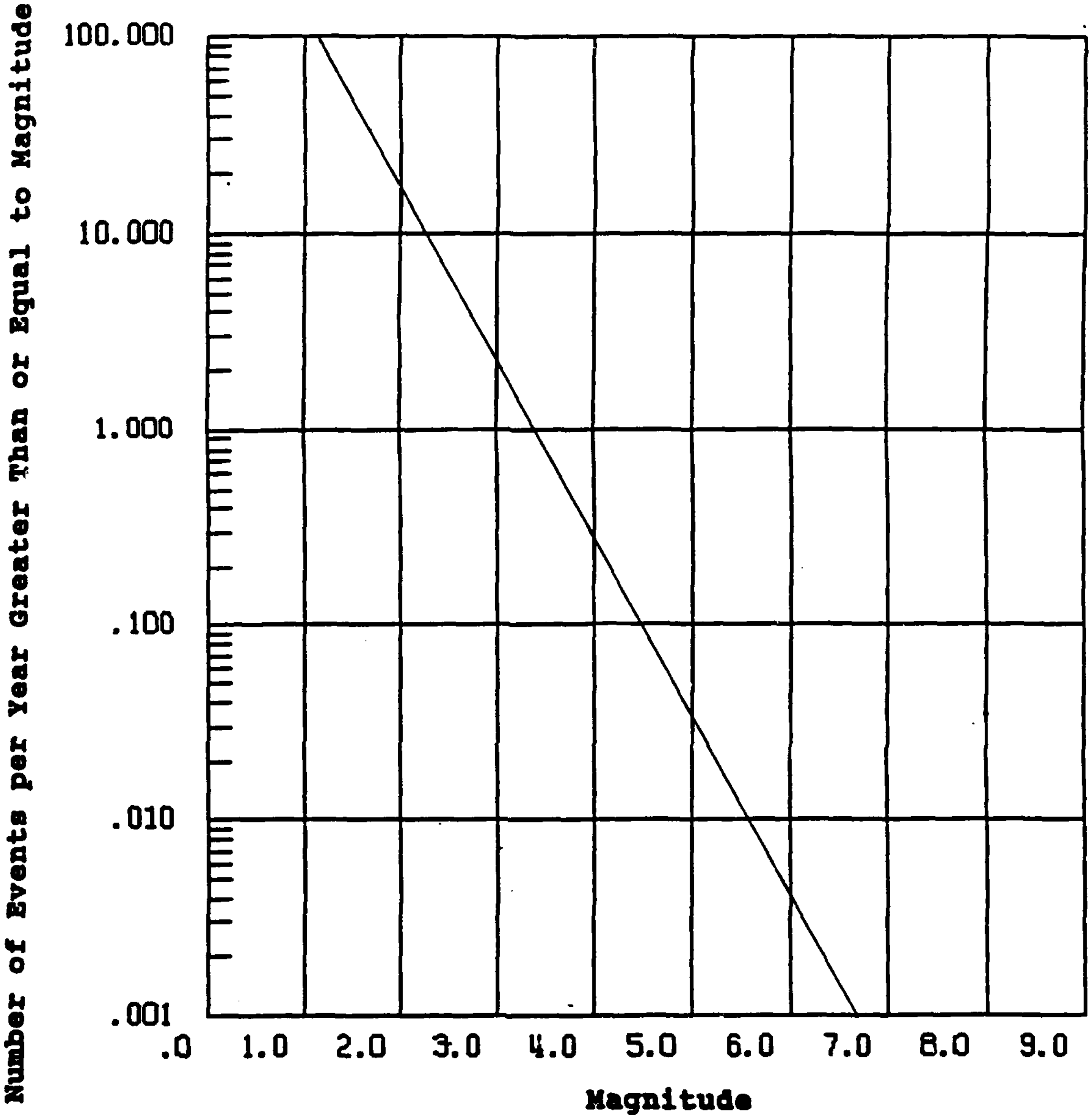


Fault - OZENA   Maximum Magnitude 7.5

Fault Longitude / Latitude Coordinates

PT1 119.32 , 34.67 PT2 119.55 , 34.8 PT3 120.02 , 35.04

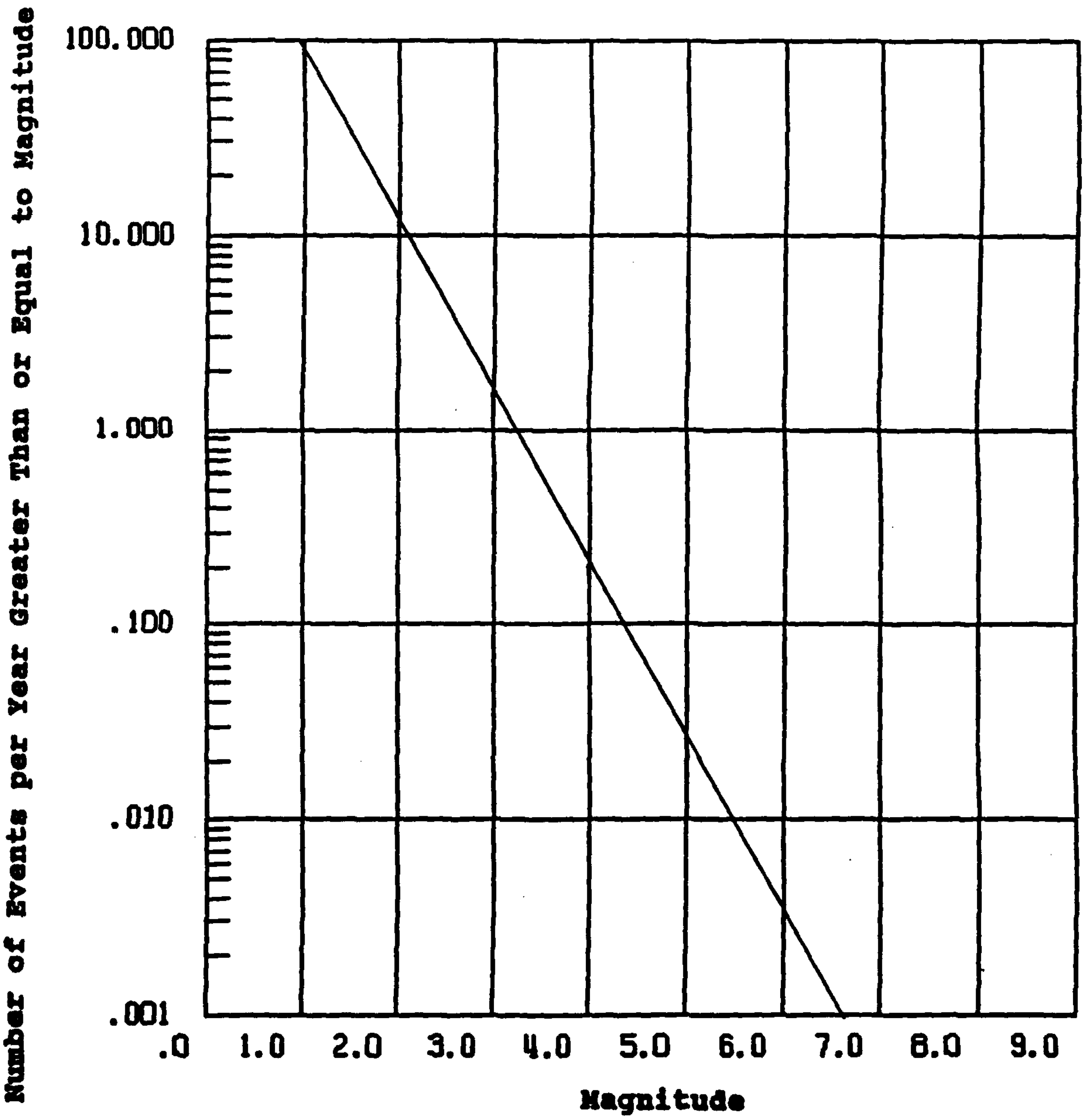
Figure A-36. Fault recurrence.



Fault - PALOS VERDE Maximum Magnitude 7

Fault Longitude / Latitude Coordinates
PT1 118.48 , 33.9 PT2 118.22 , 33.7 PT3 117.97 , 33.33

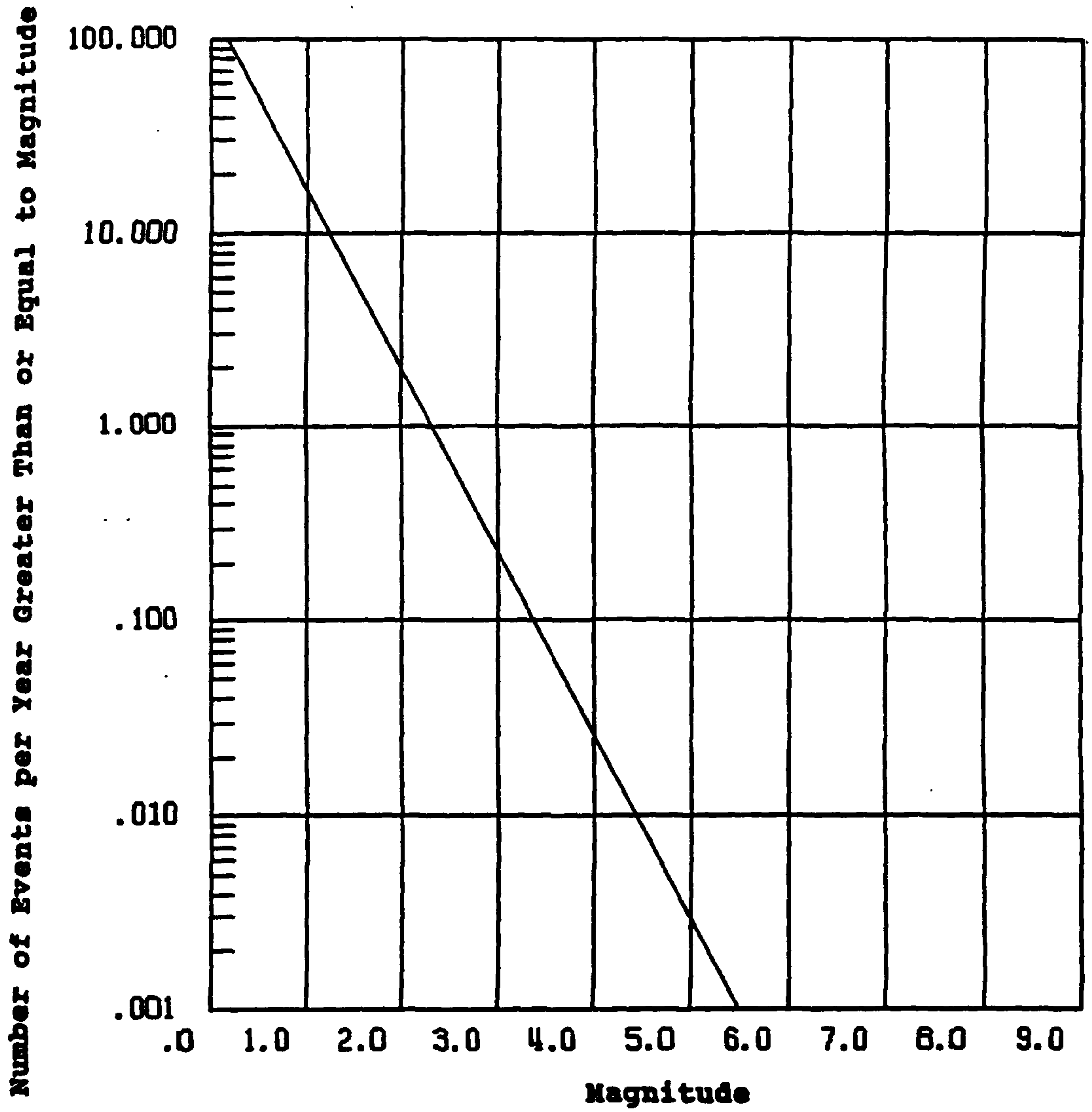
Figure A-37 . Fault recurrence.



Fault - PARAMINT ZONE Maximum Magnitude 7.25

Fault Longitude / Latitude Coordinates
PT1 117.4 , 36.33 PT2 117.3 , 36 PT3 116.96 , 35.6

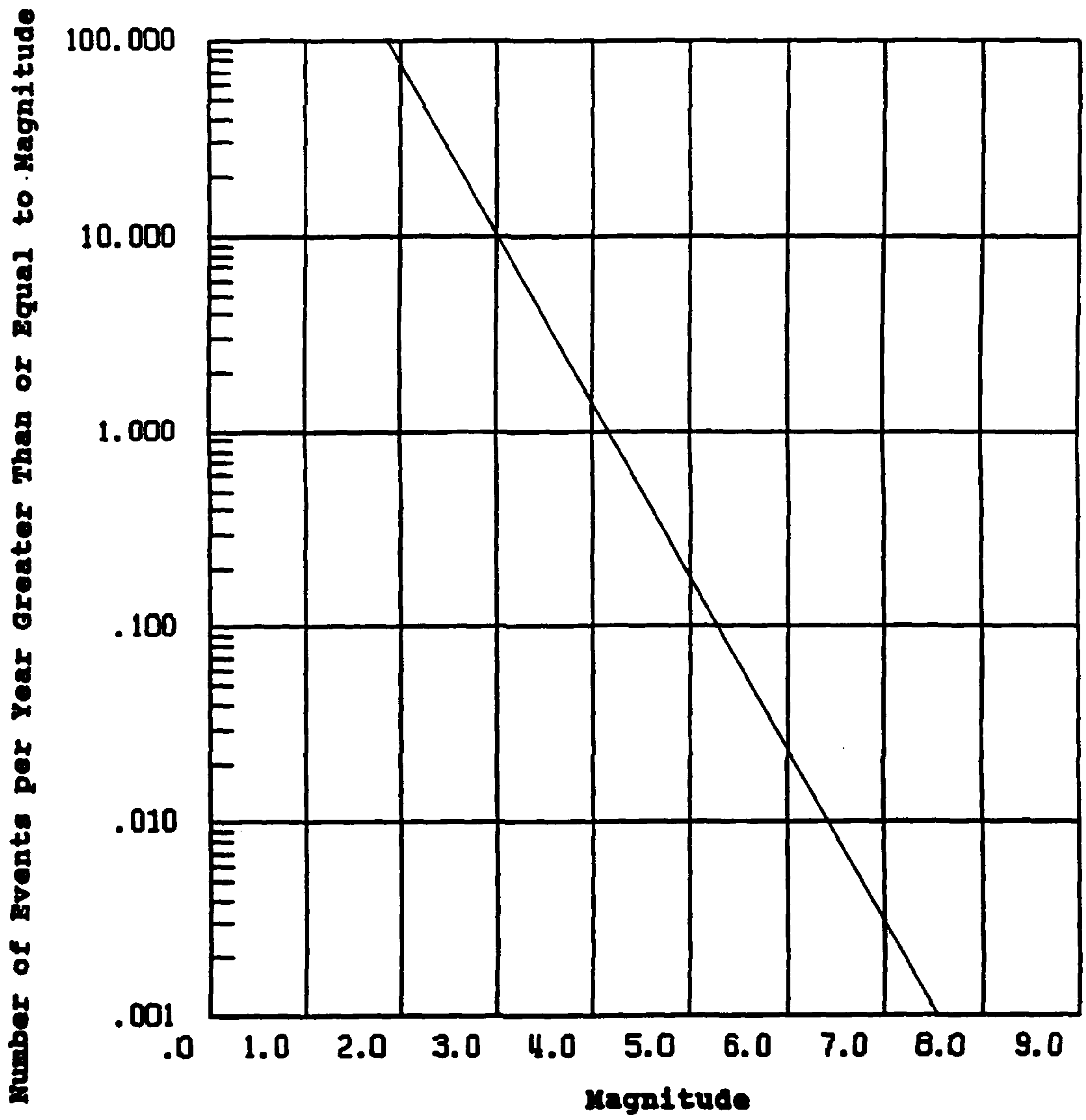
Figure A-38. Fault recurrence.



Fault - PINE MOUNTAIN Maximum Magnitude 6.75

Fault Longitude / Latitude Coordinates
PT1 119.37 , 34.65 PT2 119.04 , 34.57 PT3 118.75 , 34.62

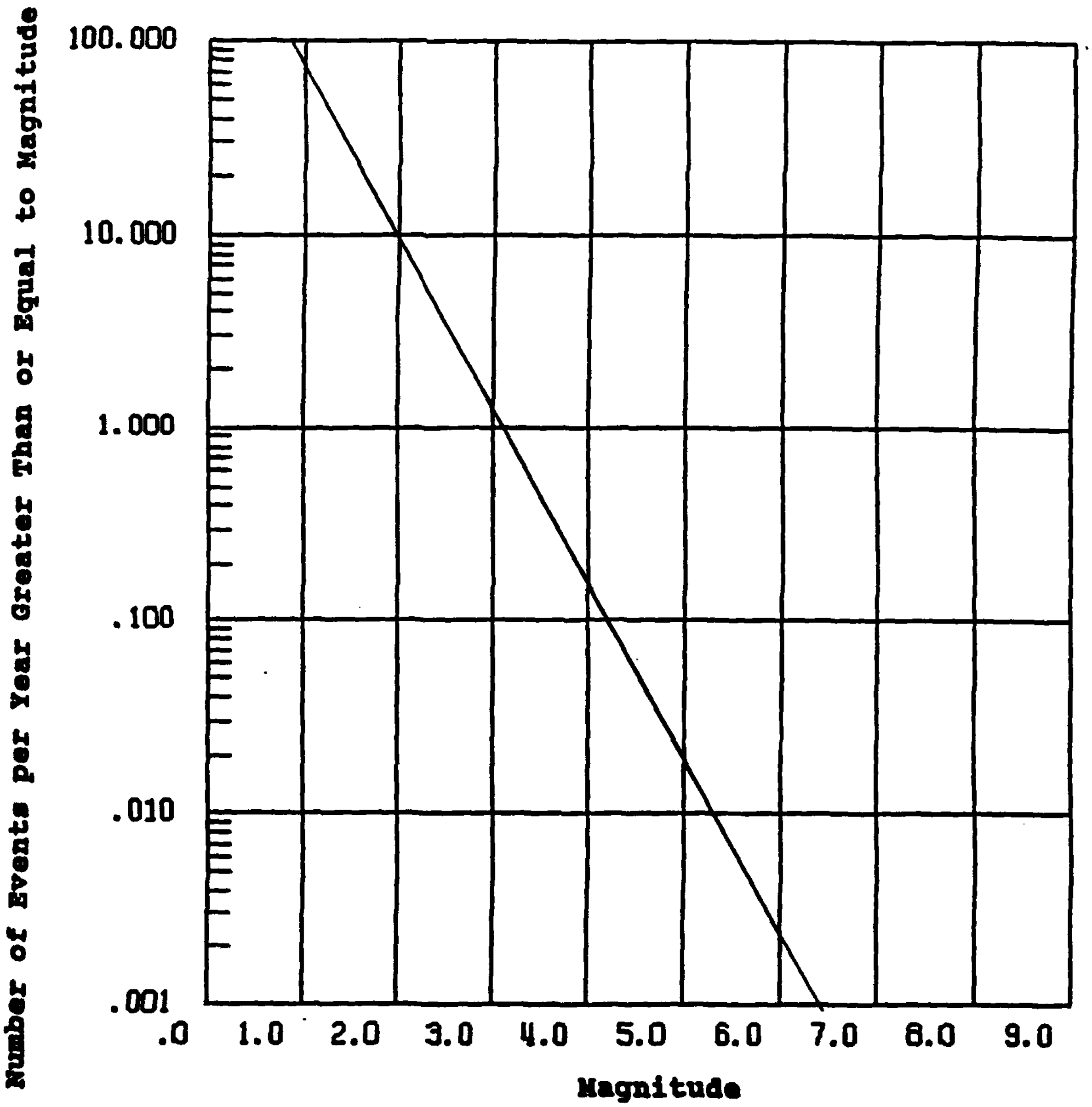
Figure A-39. Fault recurrence.



Fault - PINTO MOUNTAIN Maximum Magnitude 7.5

Fault Longitude / Latitude Coordinates
PT1 116.6 , 34.03 PT2 116.35 , 34.13 PT3 115.88 , 34.1

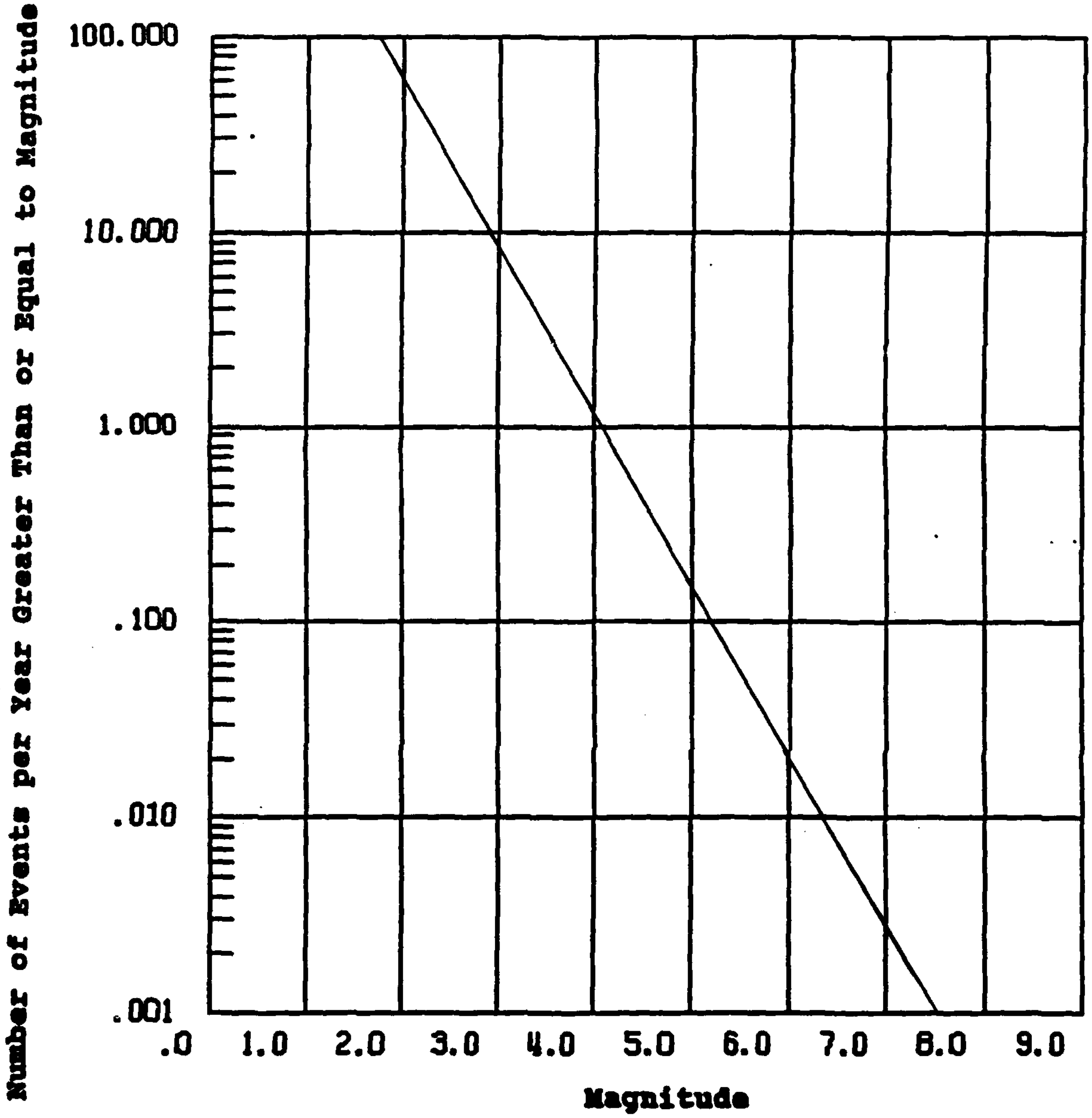
Figure A-40. Fault recurrence.



Fault - PISGAH Maximum Magnitude 7.25

Fault Longitude / Latitude Coordinates
PT1 116.49 , 34.85 PT2 116.23 , 34.47 PT3 115.9 , 34.1

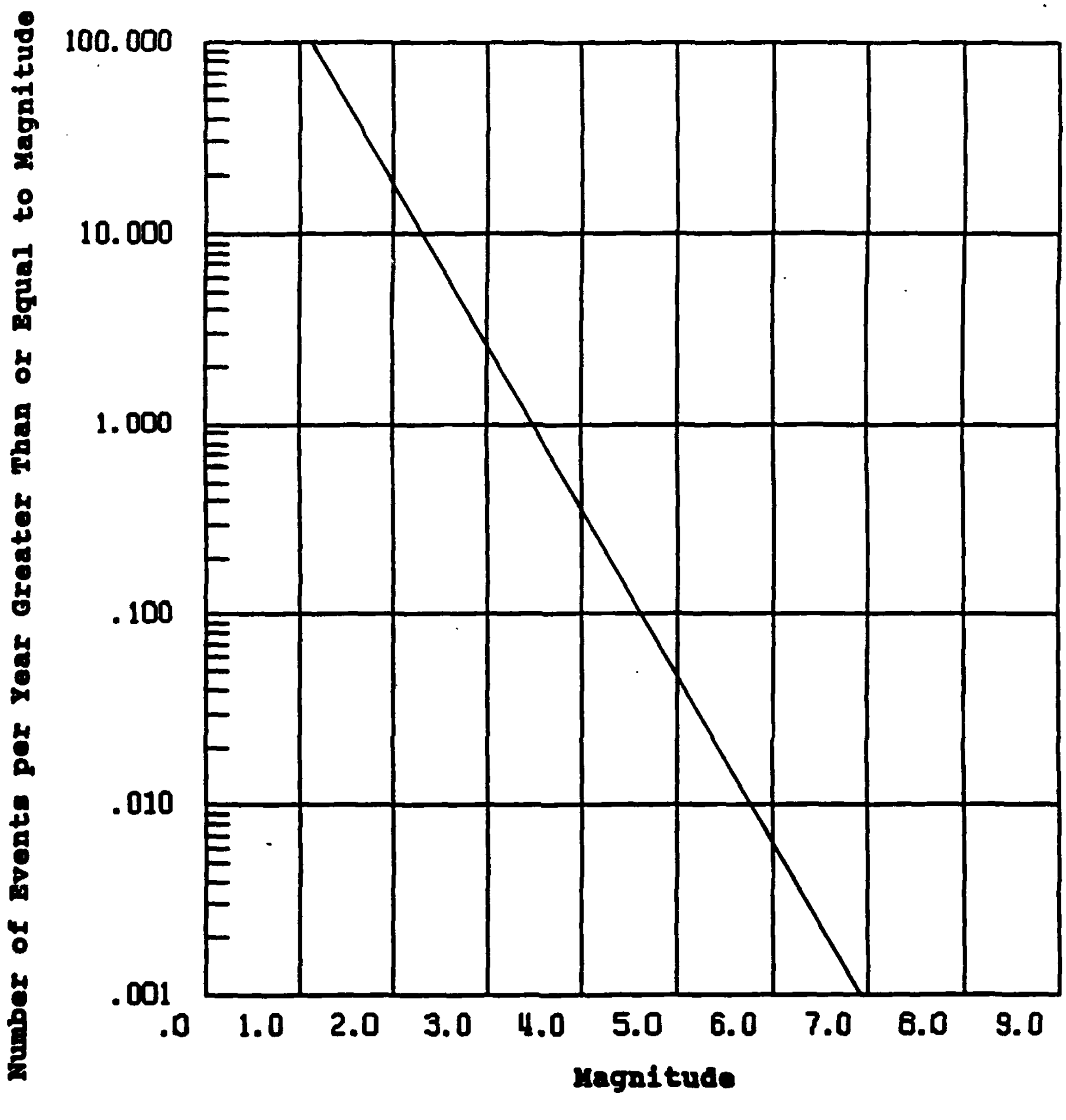
Figure A-41 . Fault recurrence.



Fault - PLEITO　　Maximum Magnitude 7

Fault Longitude / Latitude Coordinates
PT1 119.3 , 34.94　PT2 119.05 , 34.99　PT3 118.85 , 34.92

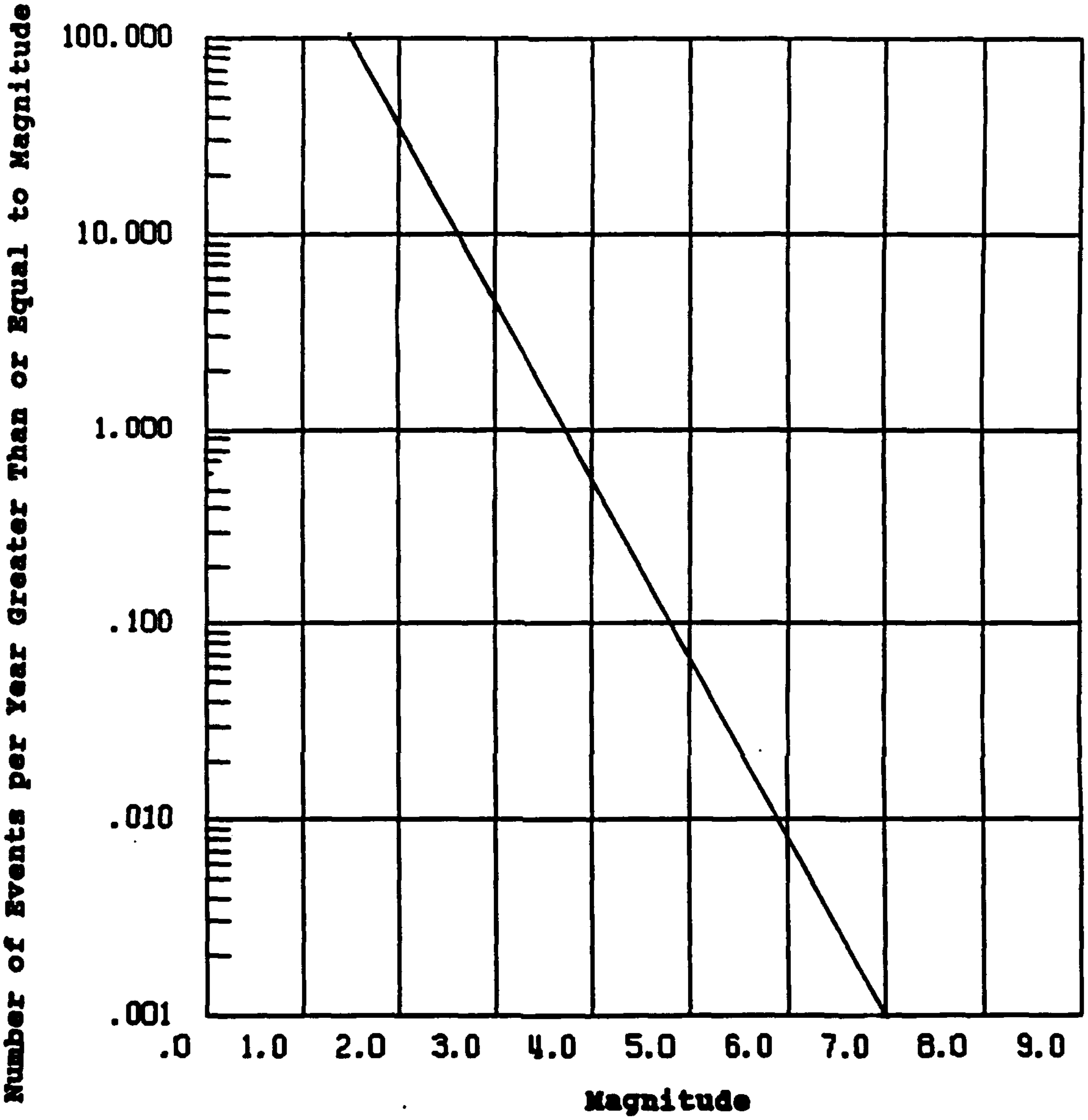
Figure A-42 . Fault recurrence.



Fault - RINCONADA **Maximum Magnitude 7.5**

Fault Longitude / Latitude Coordinates
PT1 121.74 , 36.75 PT2 120.59 , 35.42 PT3 120.1 , 35.07

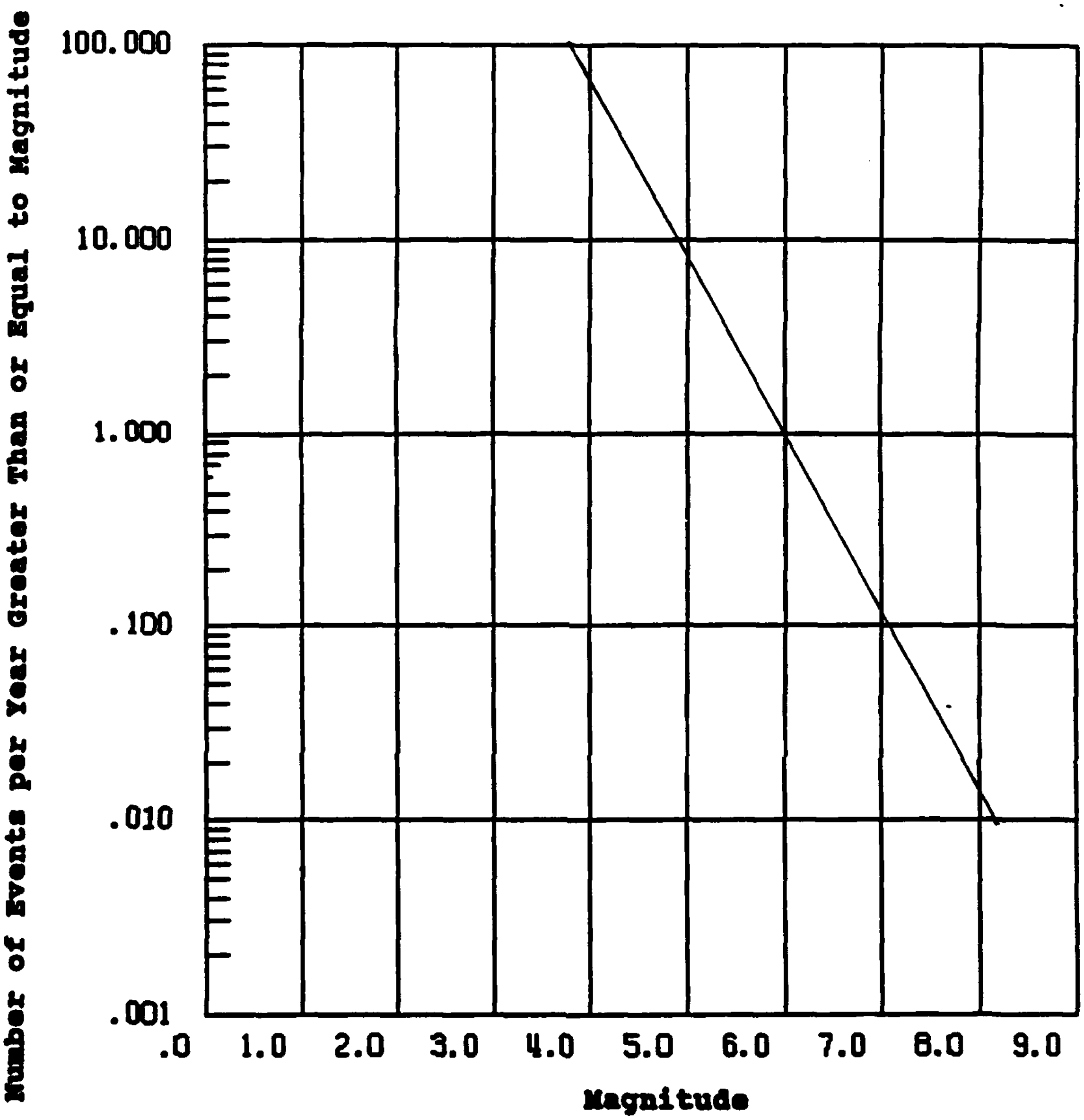
Figure A-43. Fault recurrence.



Fault - ROSE CANYON   Maximum Magnitude 7.1

Fault Longitude / Latitude Coordinates
PT1 117.35 , 33.06   PT2 117.28 , 32.87   PT3 117.05 , 32.54

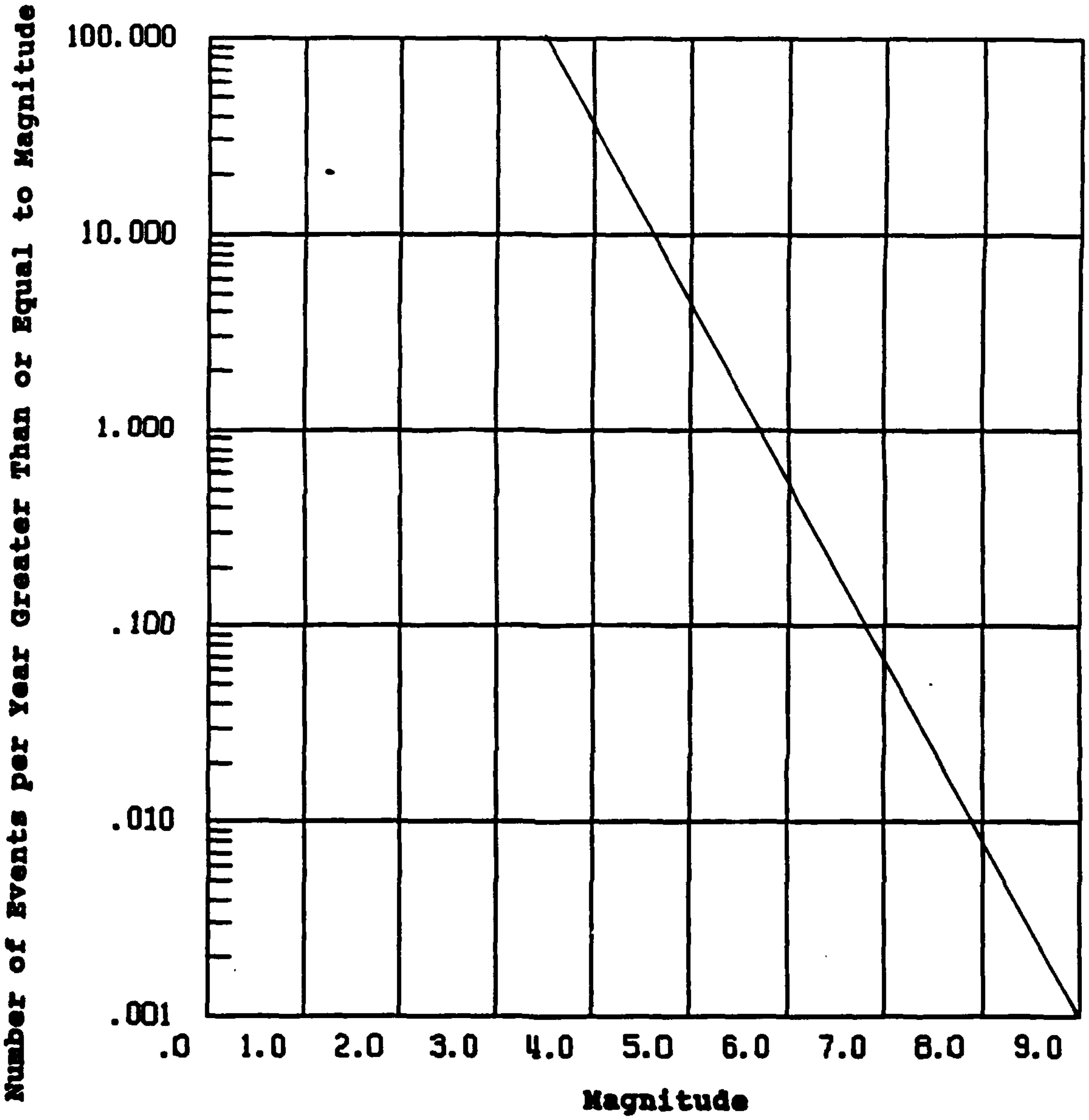
Figure A-44 . Fault recurrence.



Fault - SAN ANDREAS S. Maximum Magnitude 7.5

Fault Longitude / Latitude Coordinates
PT1 118 , 34.5 PT2 116.6 , 34.02 PT3 115.74 , 33.36

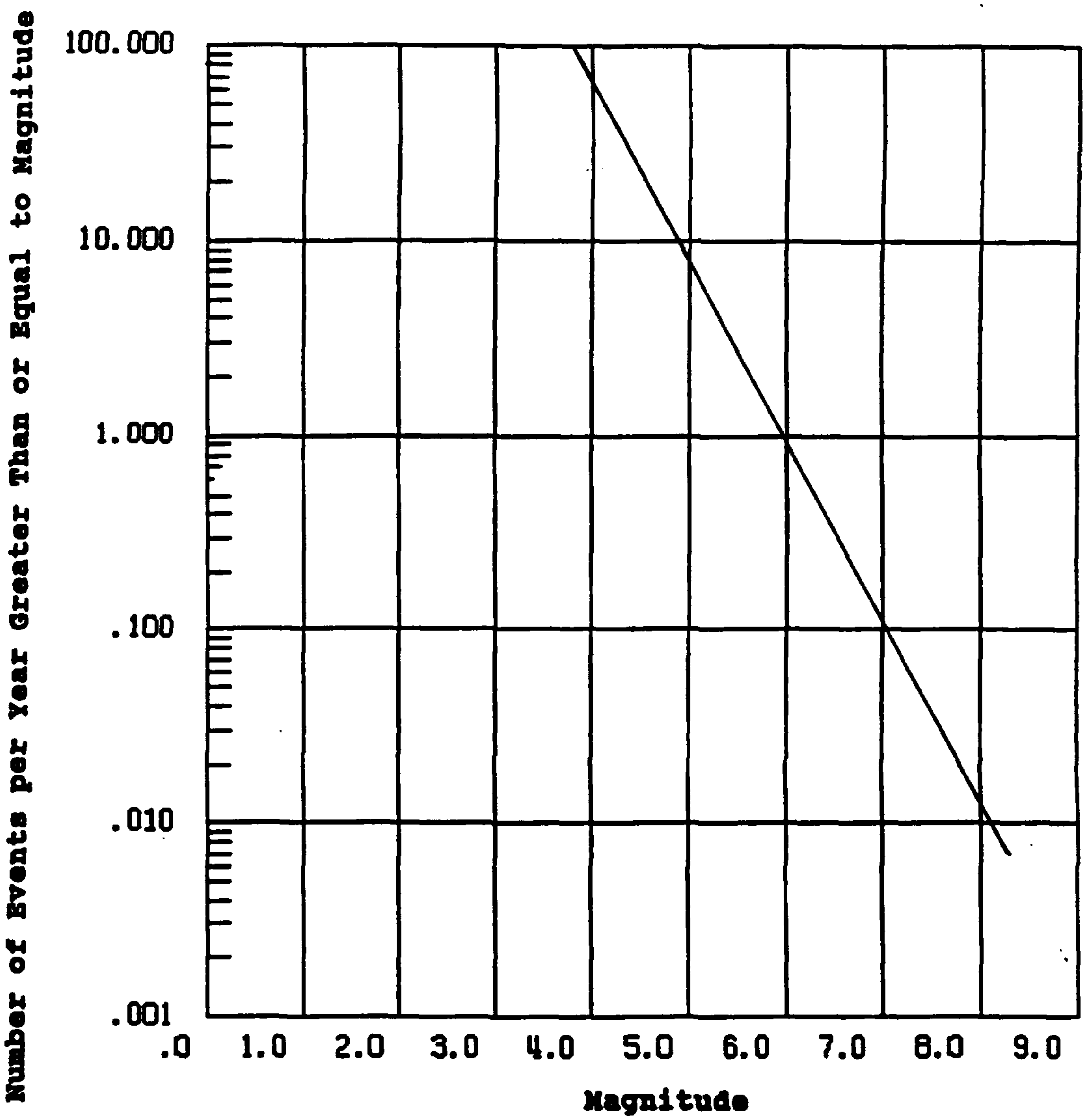
Figure A-45 . Fault recurrence.



Fault - SAN ANDREAS (CRT) **Maximum Magnitude 8.25**

Fault Longitude / Latitude Coordinates
PT1 118 , 34.5 PT2 119.4 , 34.92 PT3 121.14 , 36.55

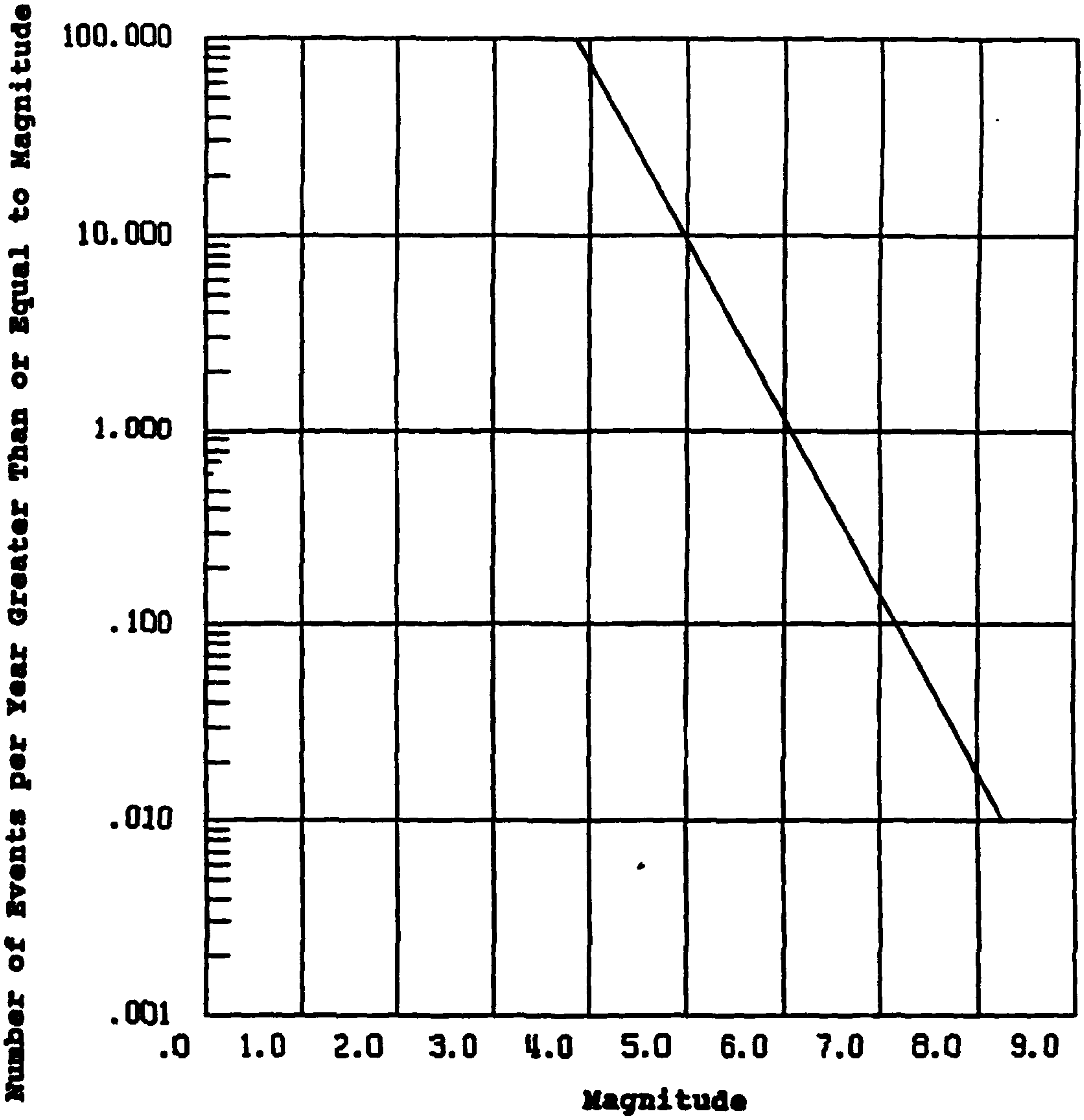
Figure A-46 . Fault recurrence.



Fault - SAN ANDREAS (SF) Maximum Magnitude 8.25

Fault Longitude / Latitude Coordinates
PT1 123.65 , 39 PT2 122.3 , 37.46 PT3 121.14 , 36.55

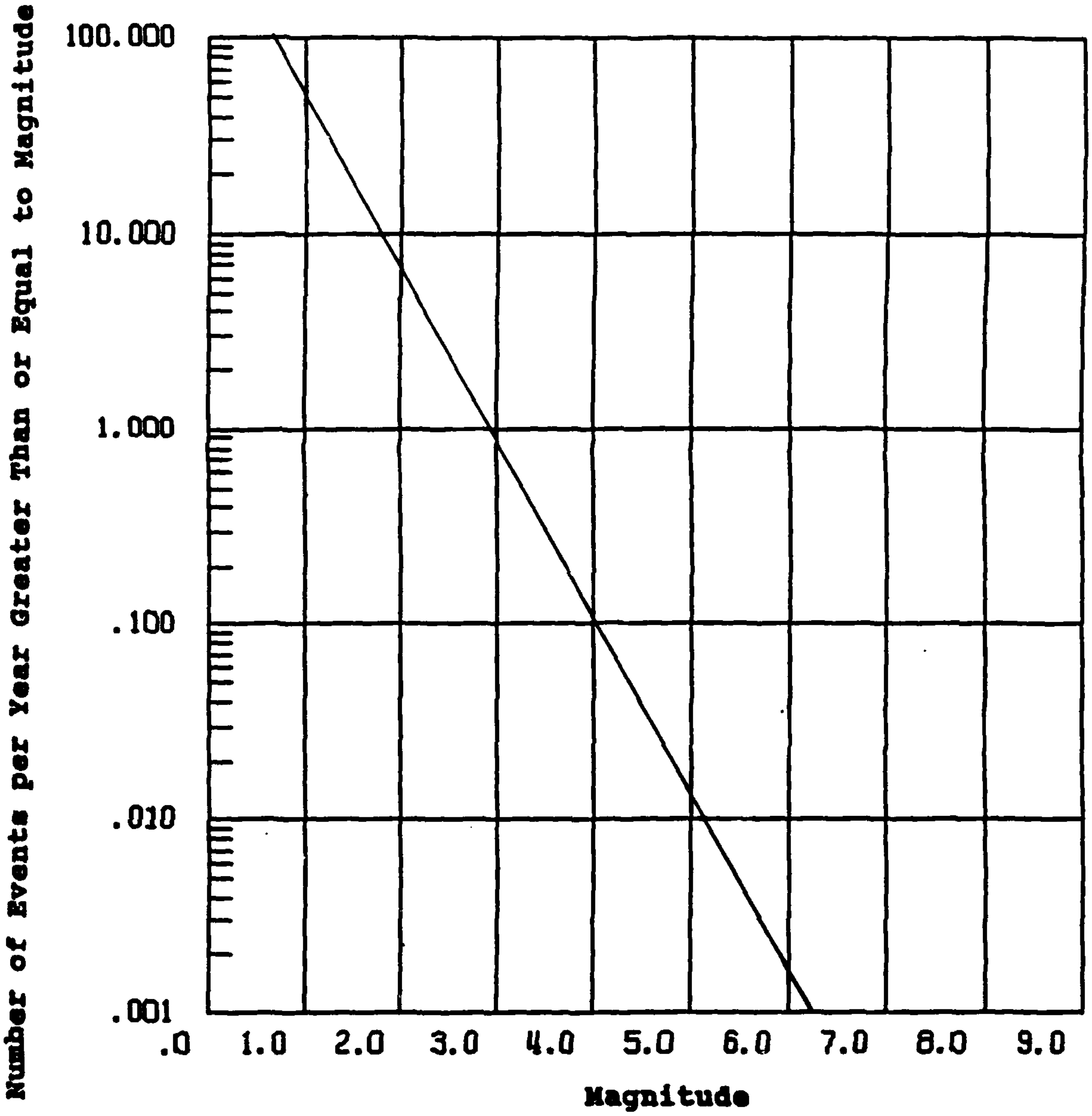
Figure A-47 . Fault recurrence.



Fault - SAN ANDREAS (North & Offshore)   Maximum Magnitude 8.25

Fault Longitude / Latitude Coordinates
PT1 123.65 , 39   PT2 124.05 , 40.03   PT3 124.9 , 40.35

Figure A-48 . Fault recurrence.



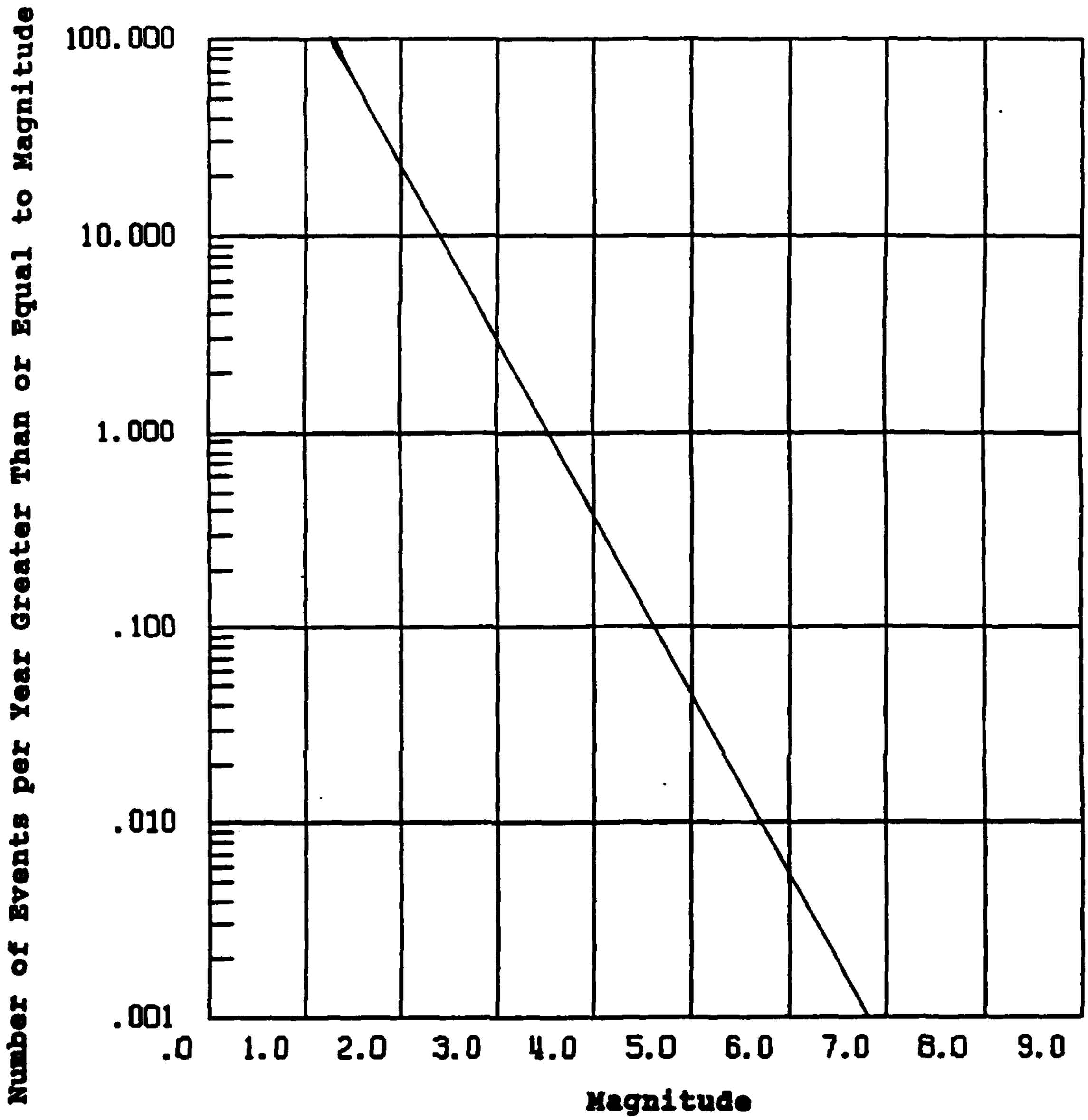
Fault - SAN CAYETANO +

Maximum Magnitude 6.75

Fault Longitude / Latitude Coordinates

PT1 119.9 , 34.42 PT2 119.17 , 34.45 PT3 118.85 , 34.38

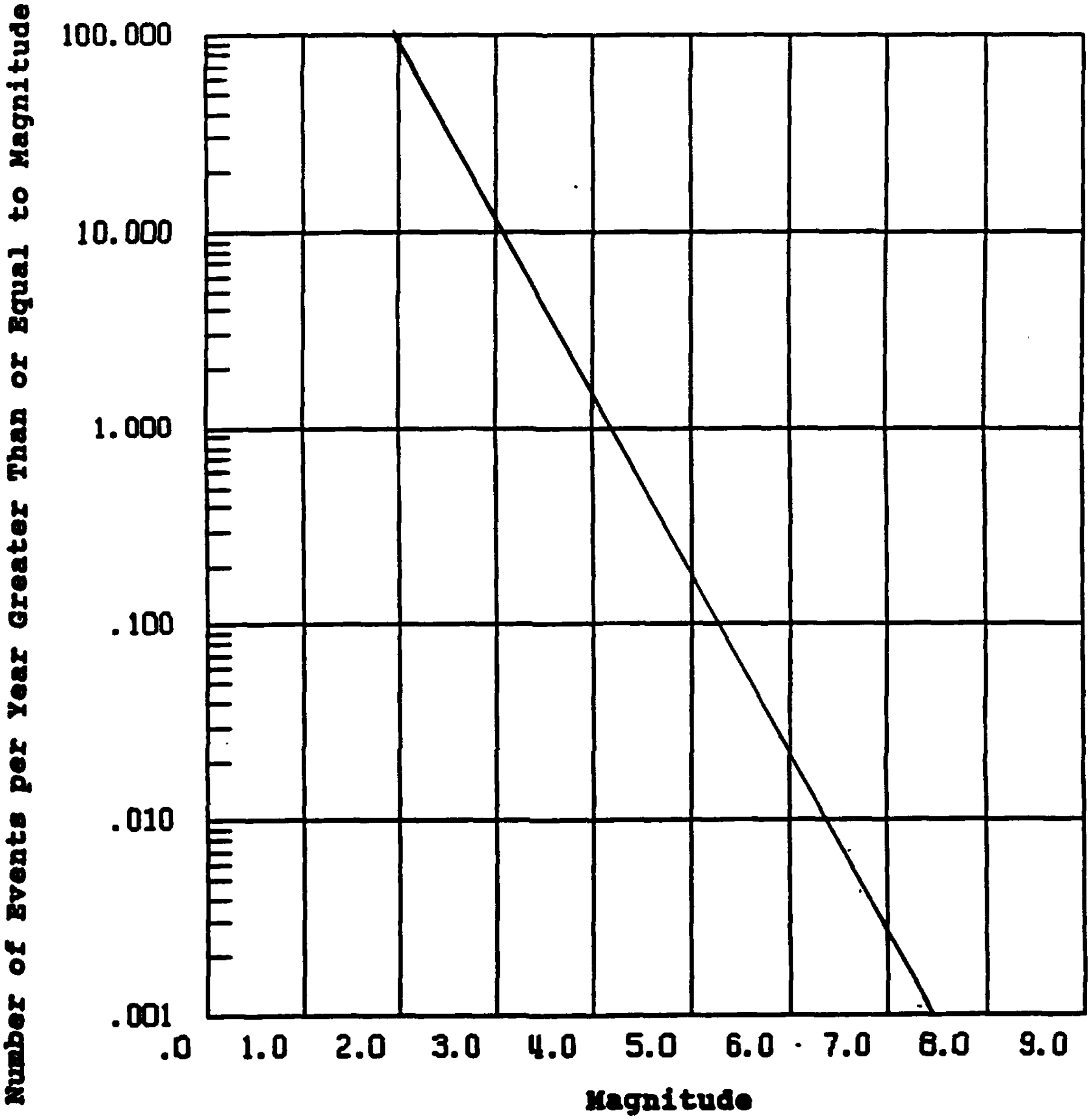
Figure A-49 . Fault recurrence.



Fault - SAN CLEMENTE Maximum Magnitude 7.7

Fault Longitude / Latitude Coordinates
PT1 117.8 , 32.47 PT2 118.3 , 32.8 PT3 118.7 , 33.19

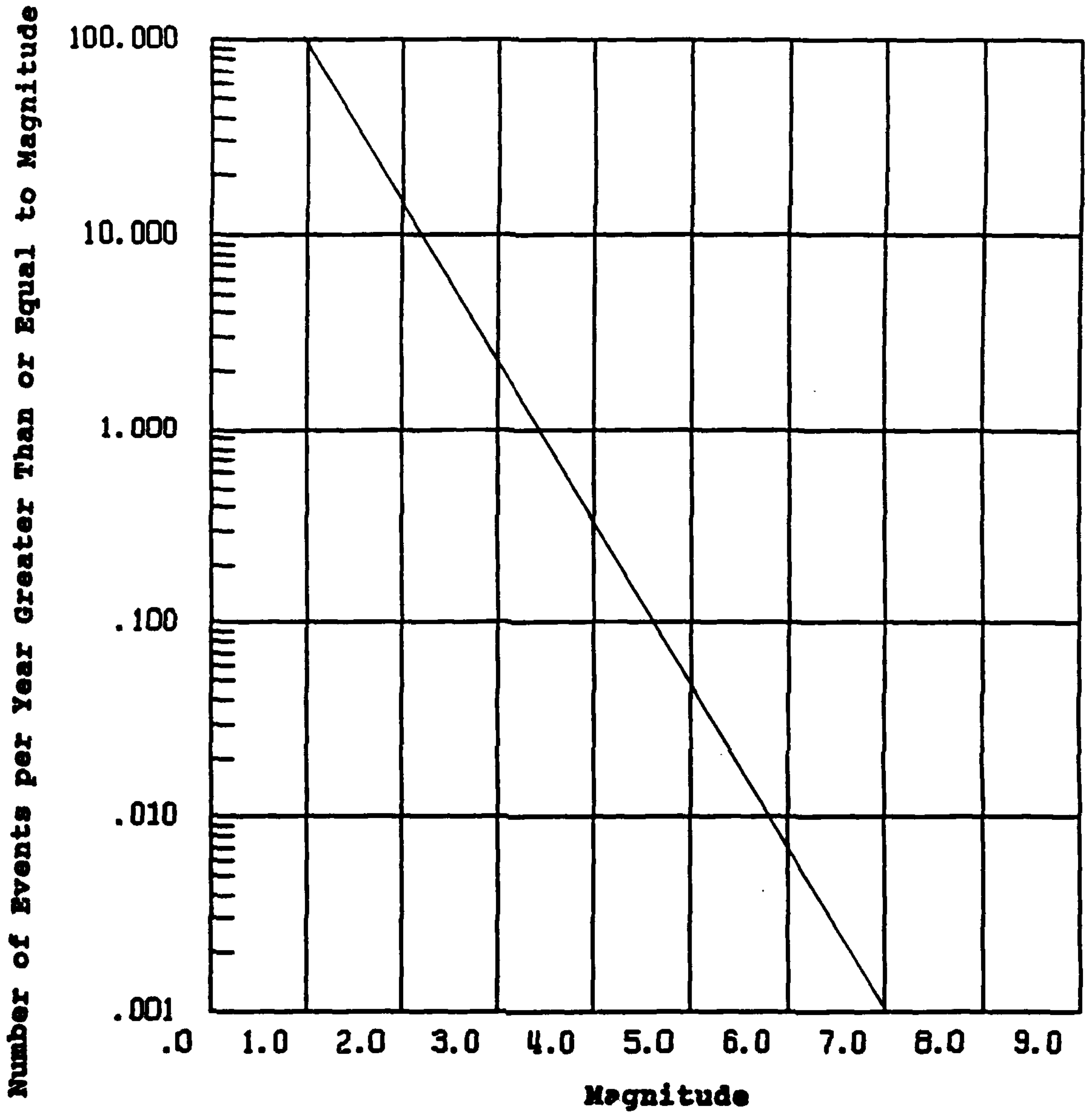
Figure A-50 . Fault recurrence.



Fault - SAN GABRIEL Maximum Magnitude 7.7

Fault Longitude / Latitude Coordinates
PT1 118.9 , 34.77 PT2 118.55 , 34.42 PT3 118.14 , 34.22

Figure A-51. Fault recurrence.



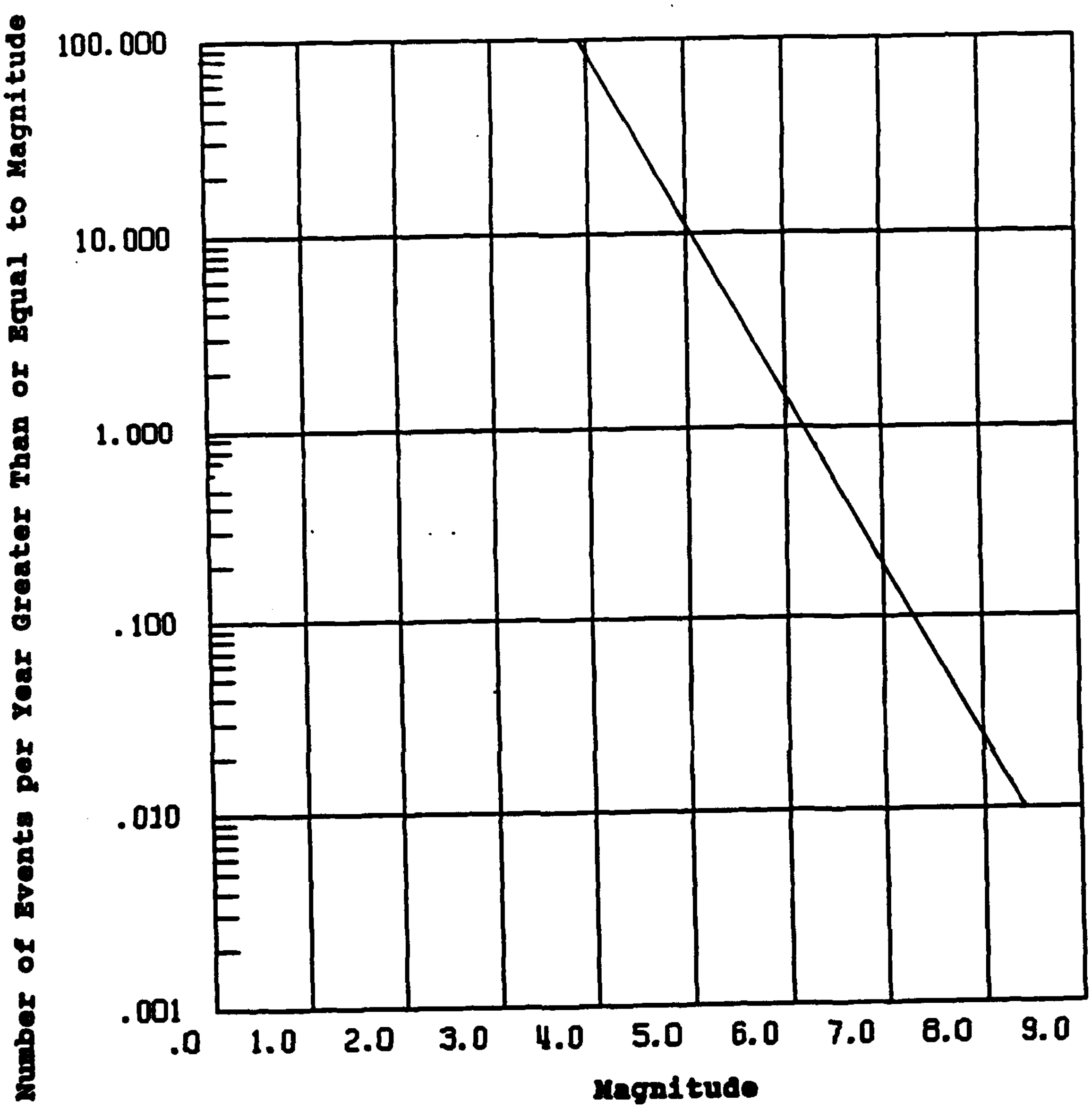
Fault - SAN GREGORIO

Maximum Magnitude 7

Fault Longitude / Latitude Coordinates

PT1 122.75 , 37.9 PT2 122.25 , 37 PT3 121.75 , 36.2

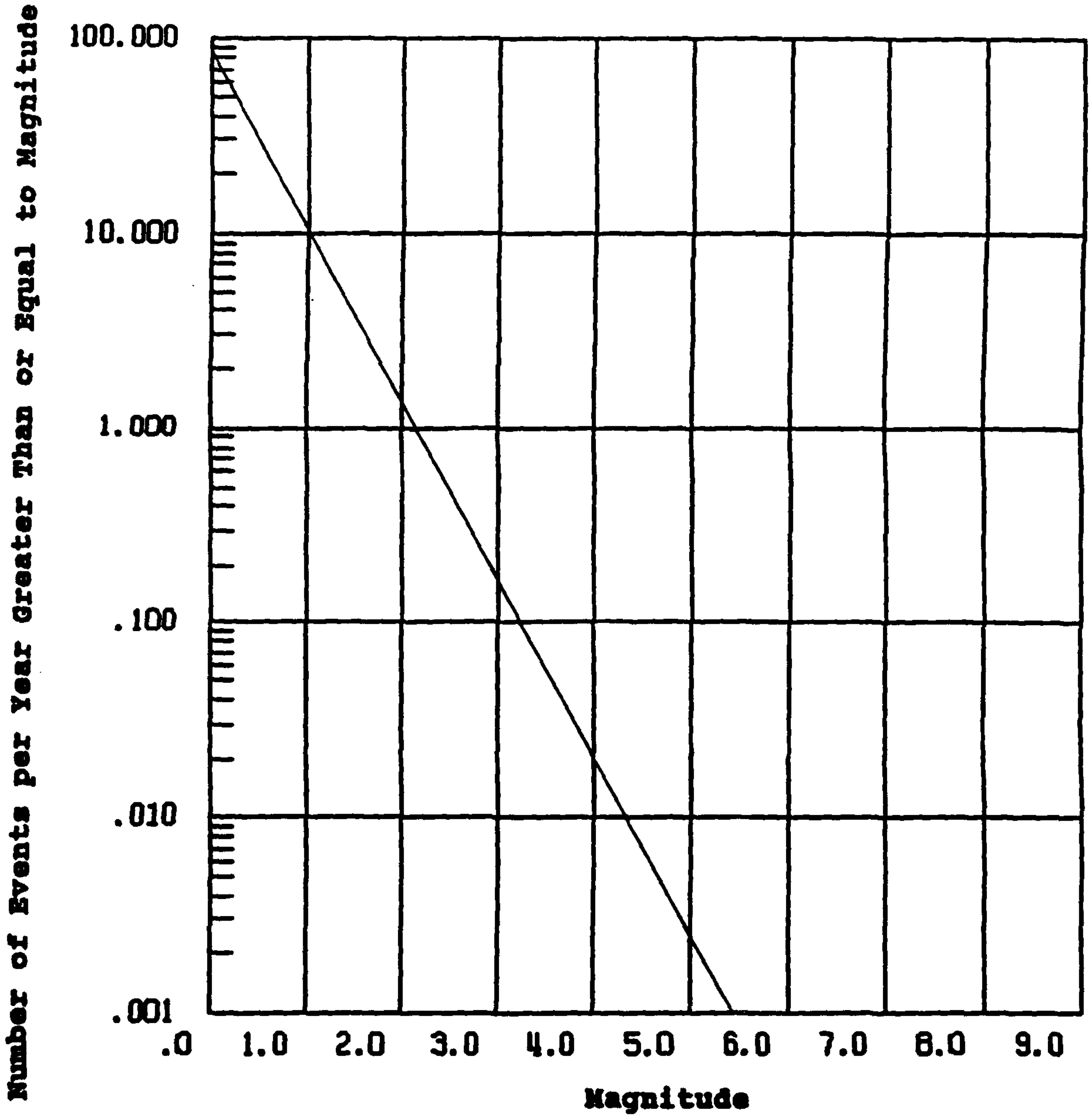
Figure A-52 . Fault recurrence.



Fault - SAN JACINTO Maximum Magnitude 7.5

Fault Longitude / Latitude Coordinates
PT1 117.62 , 34.32 PT2 116.9 , 33.75 PT3 116.13 , 33.26

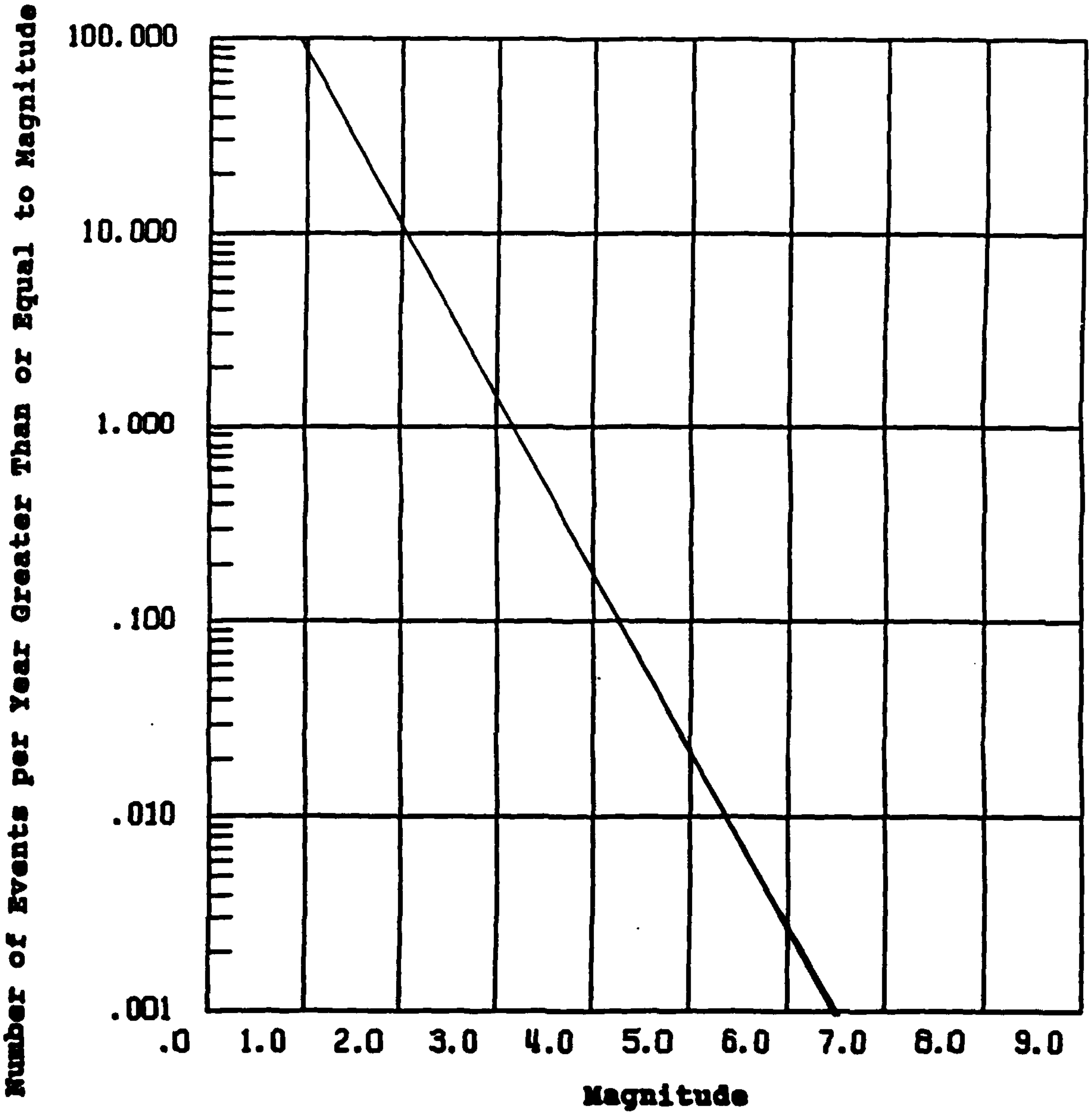
Figure A-53 . Fault recurrence.



Fault - SAN JUAN Maximum Magnitude 7

Fault Longitude / Latitude Coordinates
PT1 119.95 , 35.14 PT2 120.15 , 35.36 PT3 120.27 , 35.67

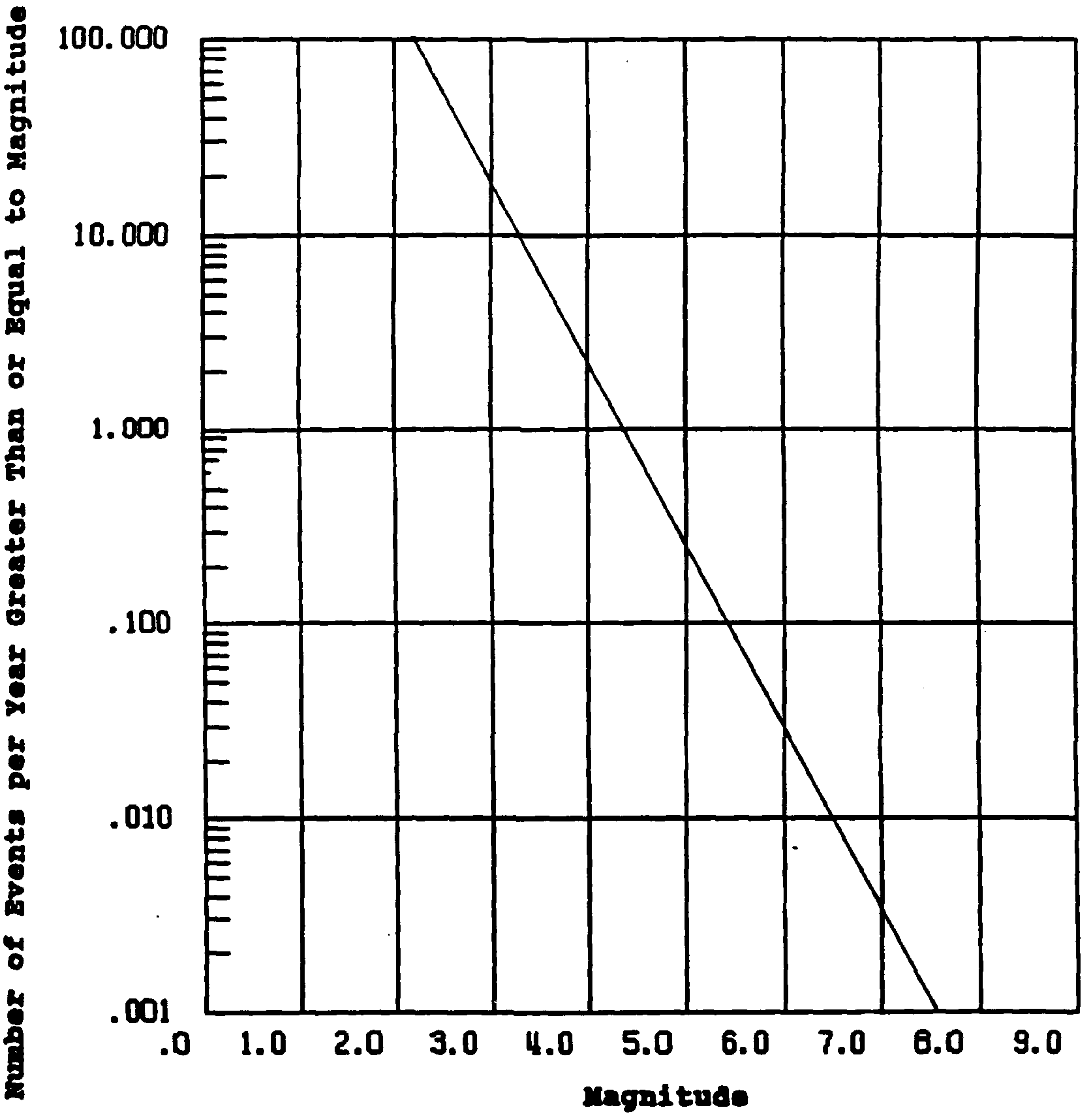
Figure A-54. Fault recurrence.



Fault - SANTA CRUZ ISLAND Maximum Magnitude 7

Fault Longitude / Latitude Coordinates
PT1 120.06 , 34.09 PT2 119.61 , 33.97 PT3 119.4 , 33.98

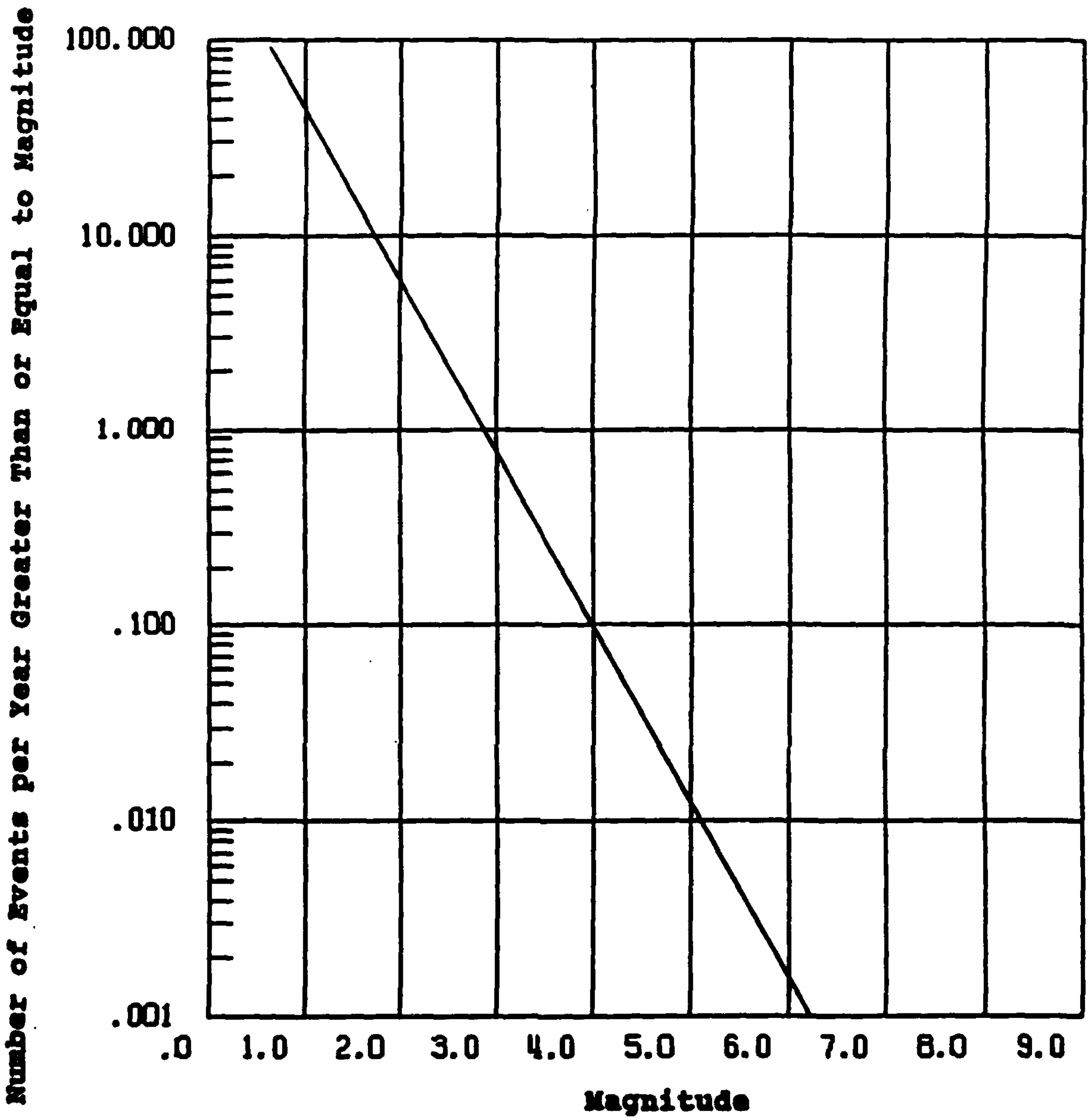
Figure A-55 . Fault recurrence.



Fault - SANTA SUSANA+ Maximum Magnitude 6.5

Fault Longitude / Latitude Coordinates
PT1 118.74 , 34.35 PT2 118.28 , 34.26 PT3 118.03 , 34.15

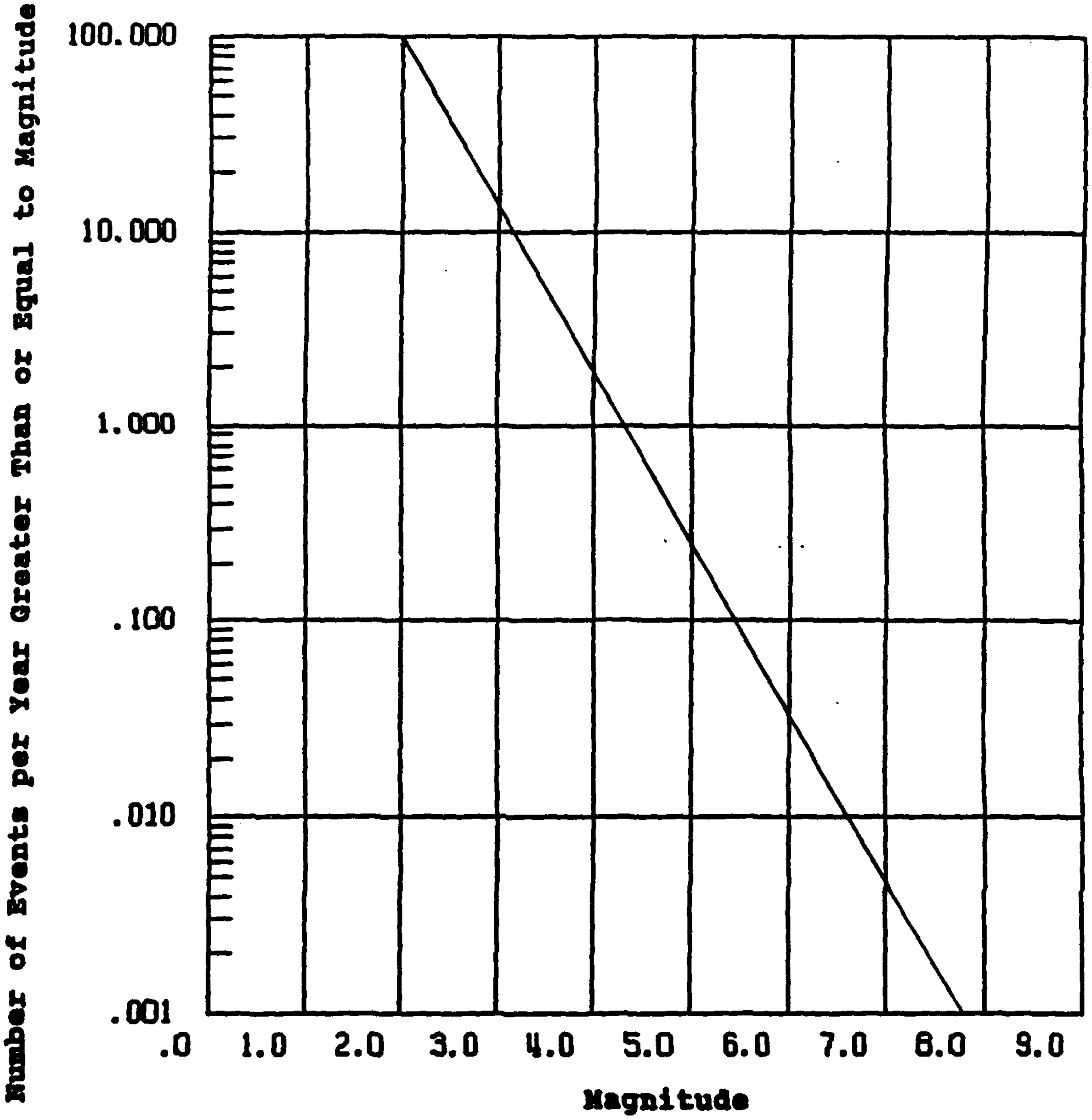
Figure A-56. Fault recurrence.



Fault - SANTA YNEZ   Maximum Magnitude 7.5

Fault Longitude / Latitude Coordinates
PT1 120.3 , 34.54   PT2 119.42 , 34.49   PT3 118.9 , 34.57

Figure A-57 . Fault recurrence.

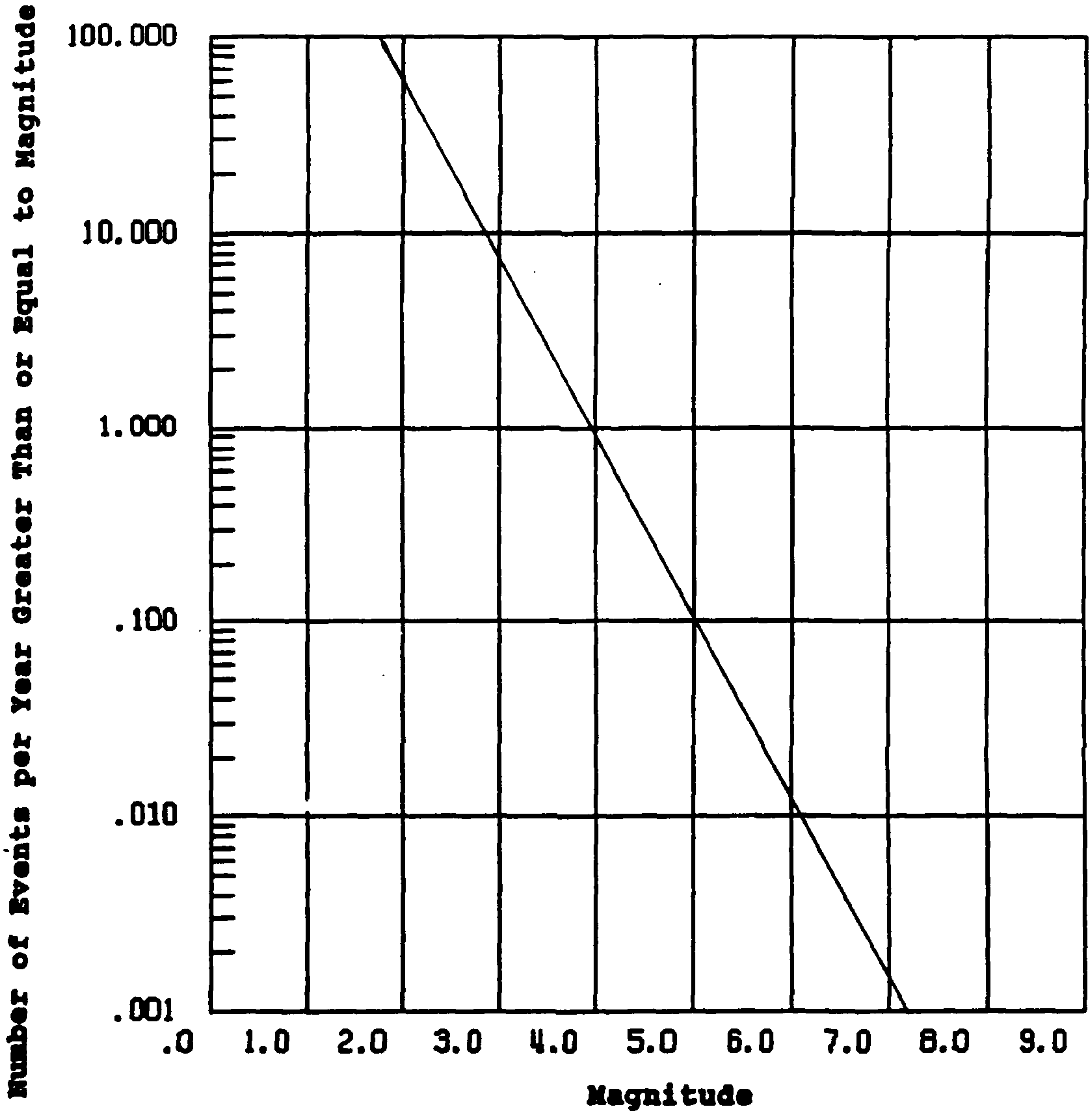


Fault - SIERRA NEVADA

Maximum Magnitude 7.5

Fault Longitude / Latitude Coordinates
PT1 118.05 , 35.27 PT2 118 , 36.15 PT3 118.48 , 37.34

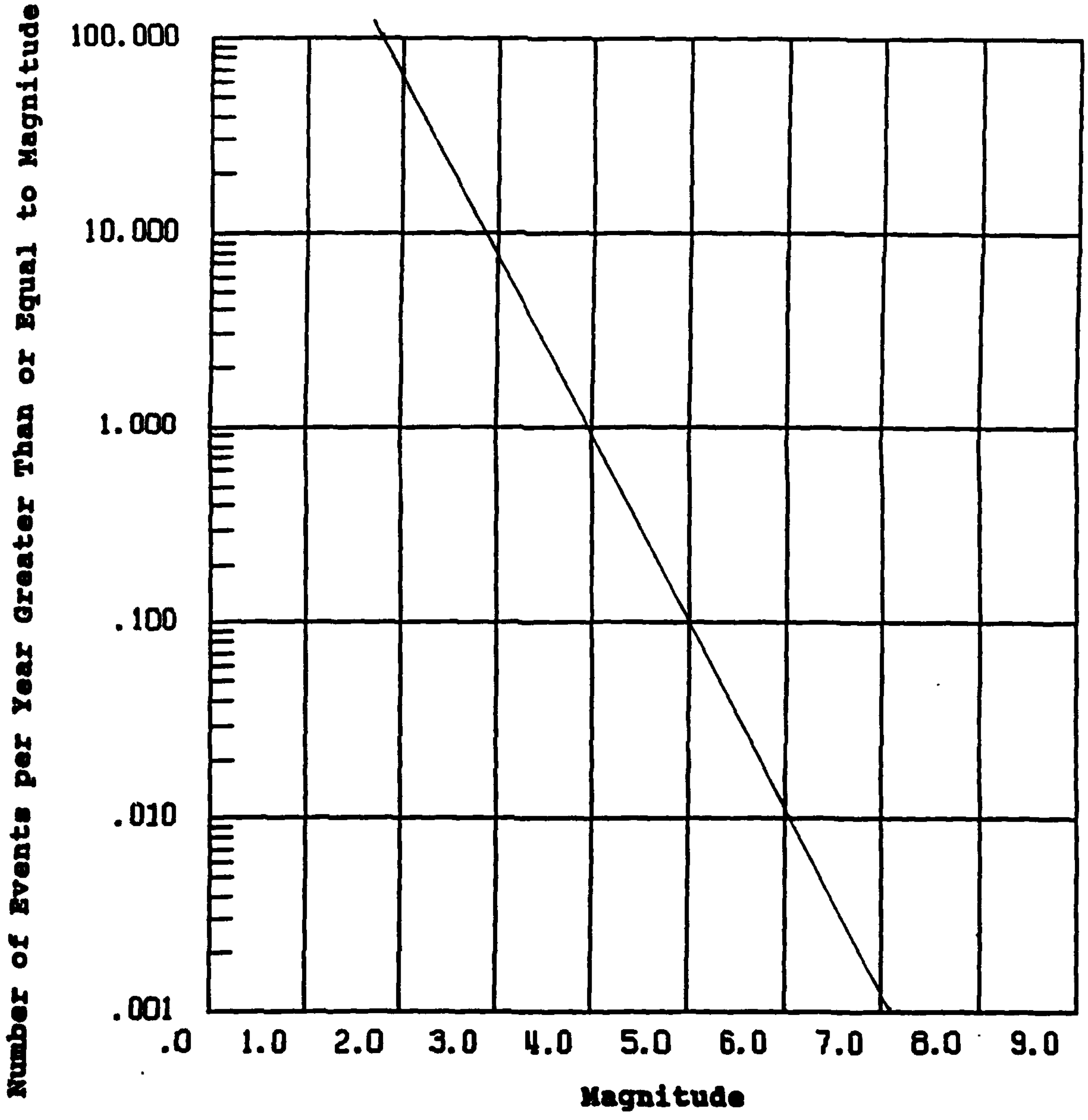
Figure A-58 . Fault recurrence.



Fault - SUPERSTITION HILL **Maximum Magnitude 7**

Fault Longitude / Latitude Coordinates
PT1 115.85 , 33.02 PT2 115.65 , 32.9 PT3 115.47 , 32.77

Figure A-59 . Fault recurrence.



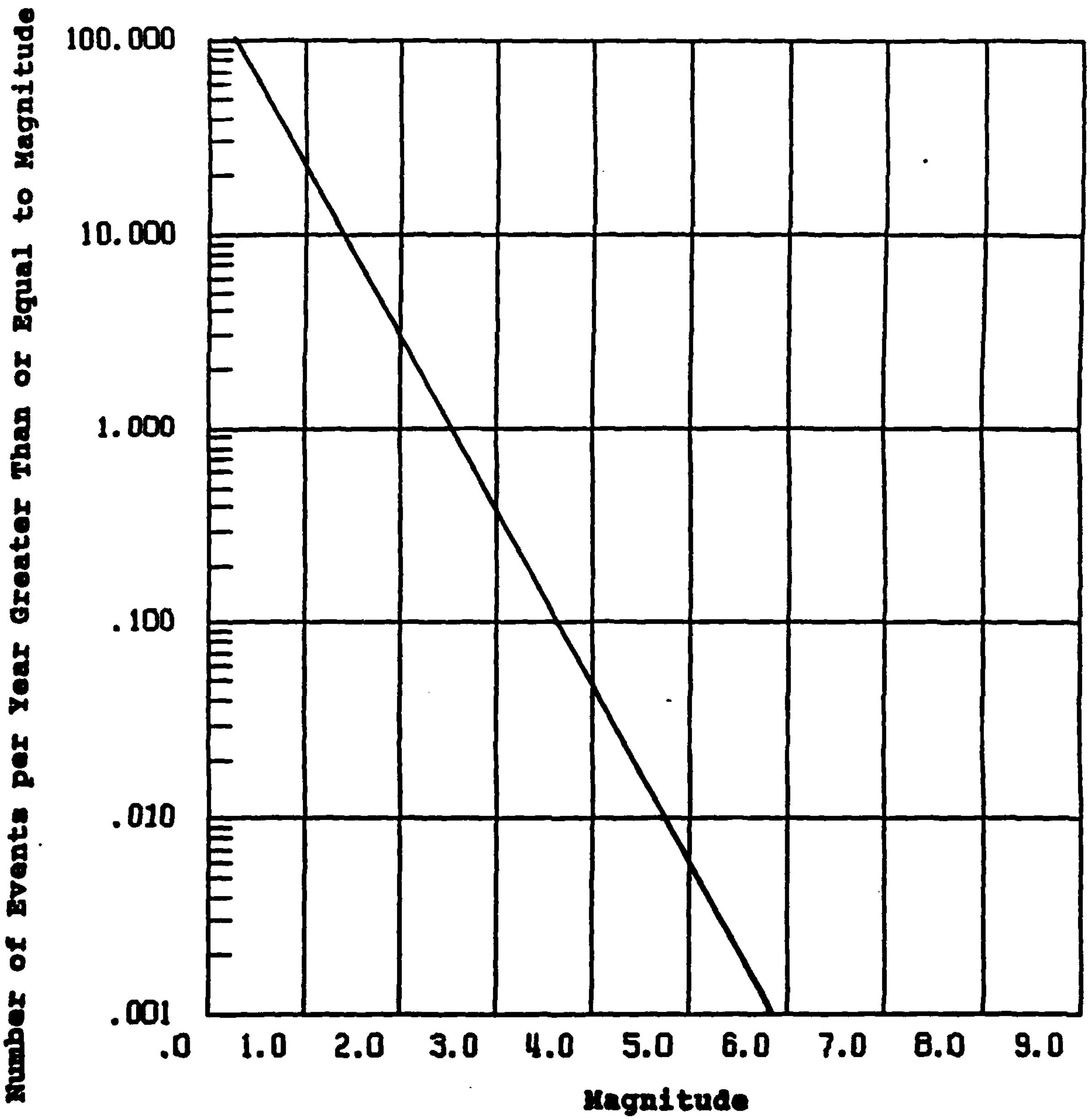
Fault - SUPERSTITION MT

Maximum Magnitude 7

Fault Longitude / Latitude Coordinates

PT1 115.95 , 32.98 PT2 115.71 , 32.89 PT3 115.47 , 32.75

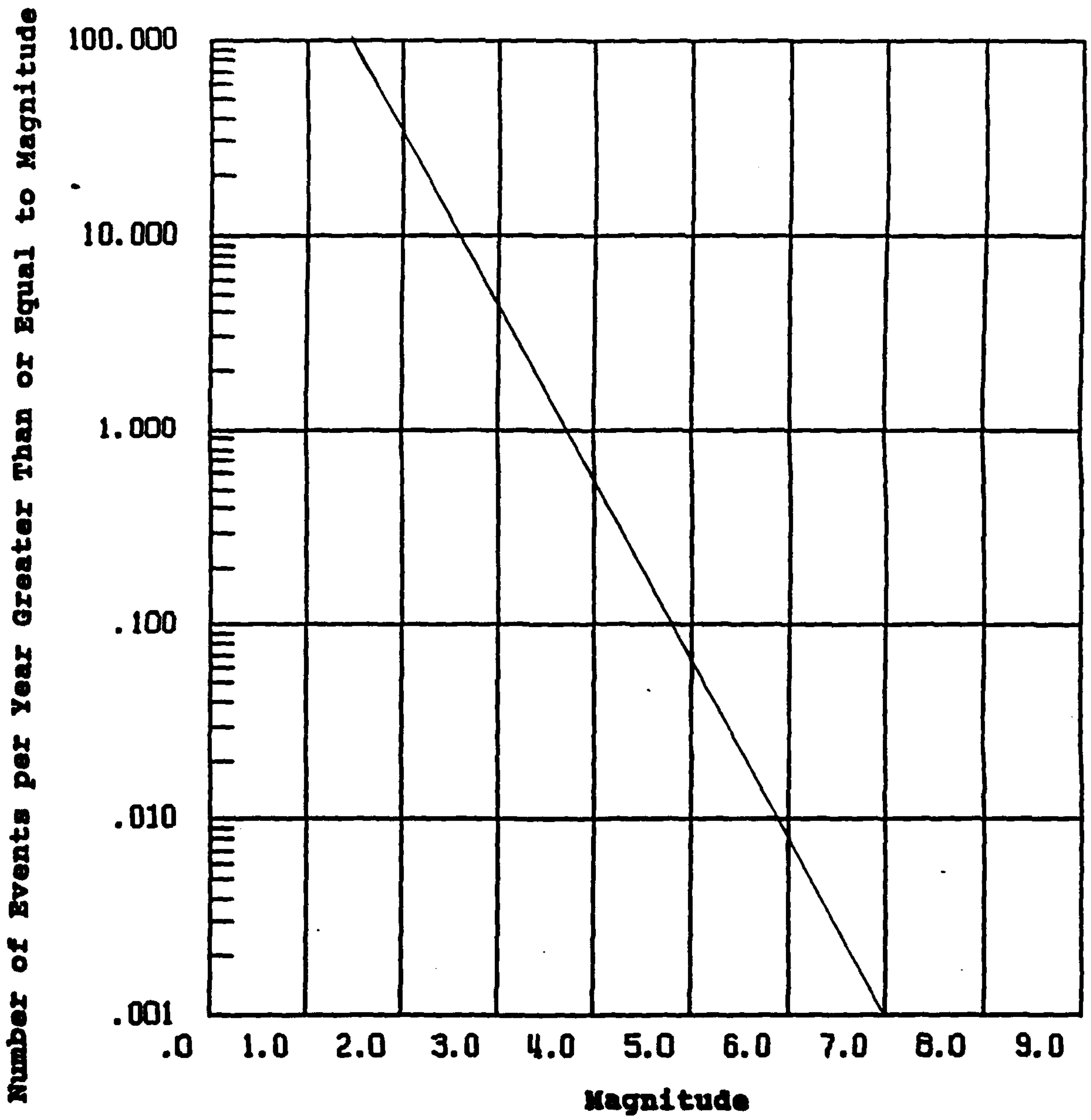
Figure A-60 . Fault recurrence.



Fault - SURPRISE Maximum Magnitude 7.5

Fault Longitude / Latitude Coordinates
PT1 120.15 , 41.9 PT2 120.2 , 41.53 PT3 120 , 41.15

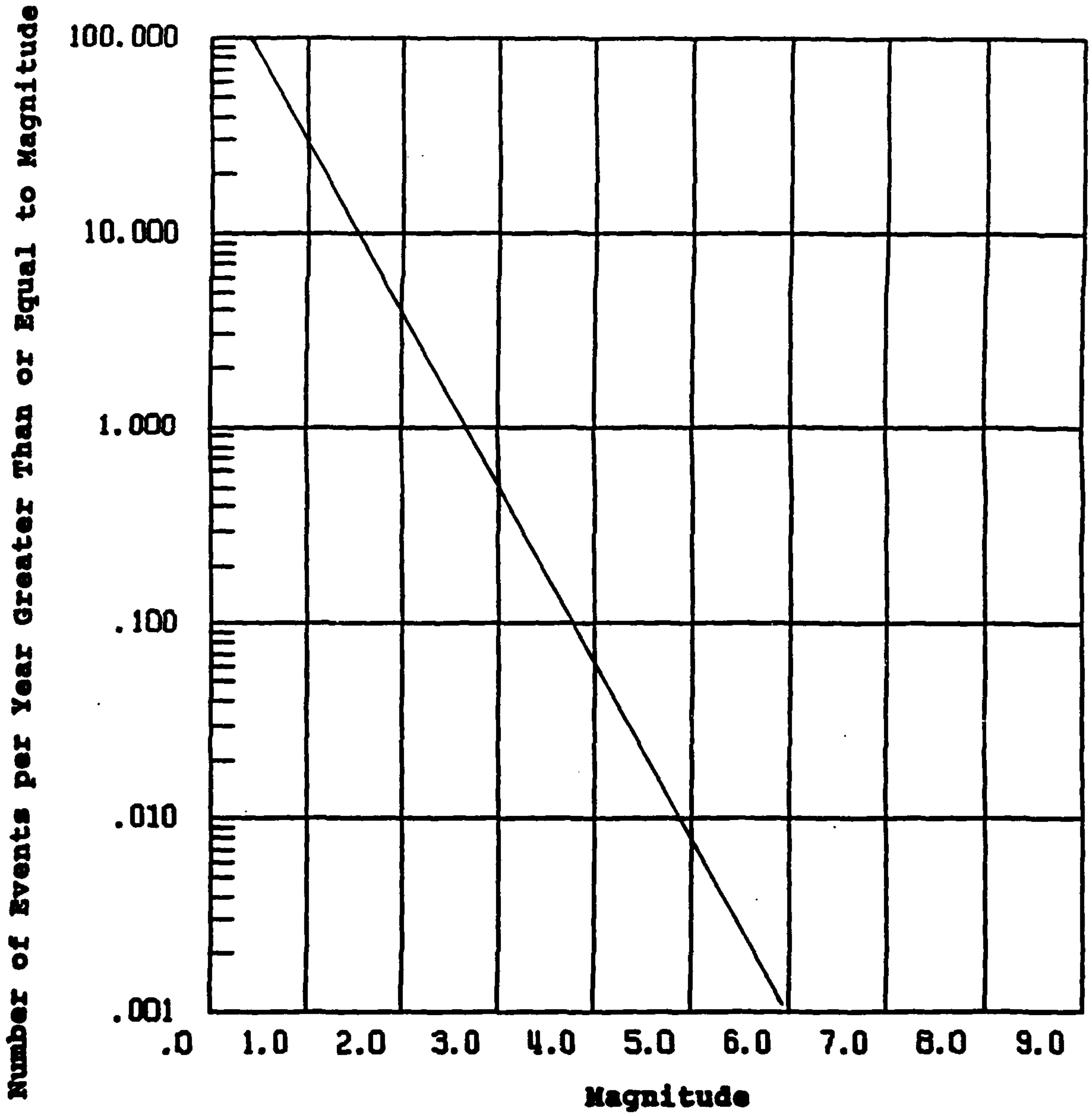
Figure A-61. Fault recurrence.



Fault - UNNAMED (Offshore N of San Diego) Maximum Magnitude 7

Fault Longitude / Latitude Coordinates
PT1 117.9 , 33.58 PT2 117.65 , 33.35 PT3 117.35 , 33.06

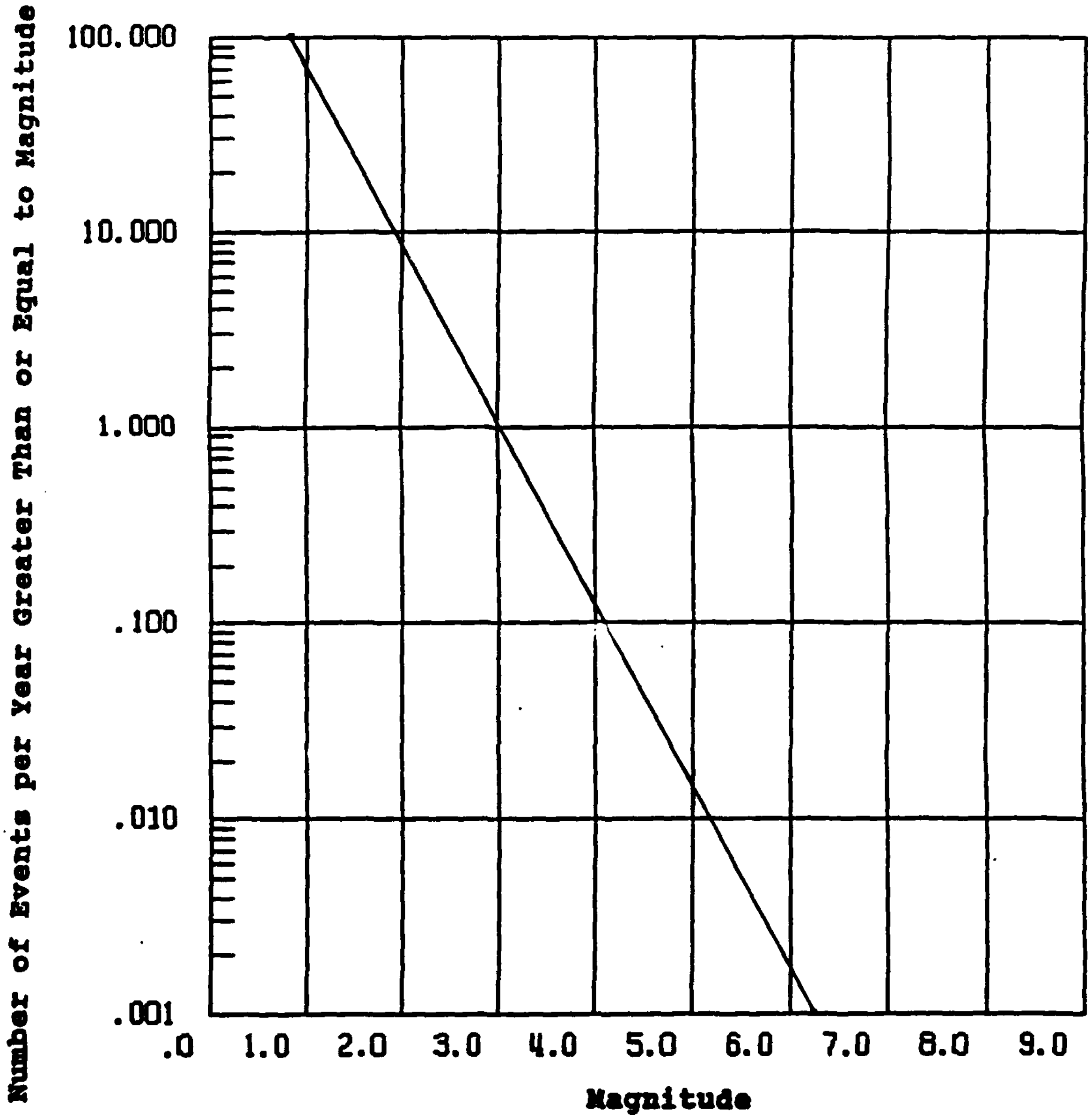
Figure A-62. Fault recurrence.



Fault - UN-NAMED 1 Maximum Magnitude 6.6

Fault Longitude / Latitude Coordinates
PT1 116.8 , 35.33 PT2 116.62 , 35.31 PT3 116.35 , 35.3

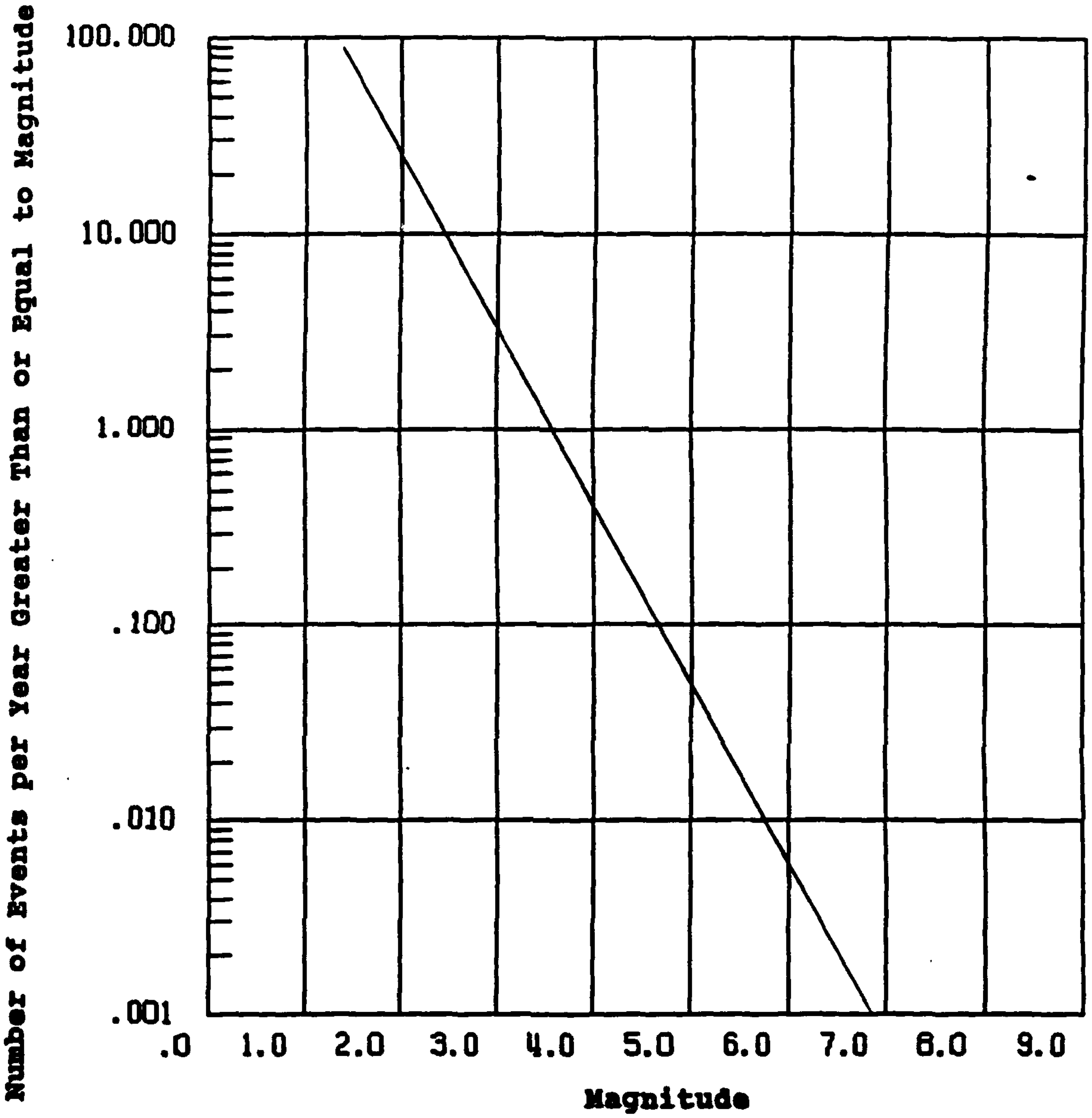
Figure A-63 . Fault recurrence.



Fault - UN-NAMED 2 Maximum Magnitude 6.9

Fault Longitude / Latitude Coordinates
PT1 117.05 , 35.47 PT2 116.58 , 35.43 PT3 116.34 , 35.38

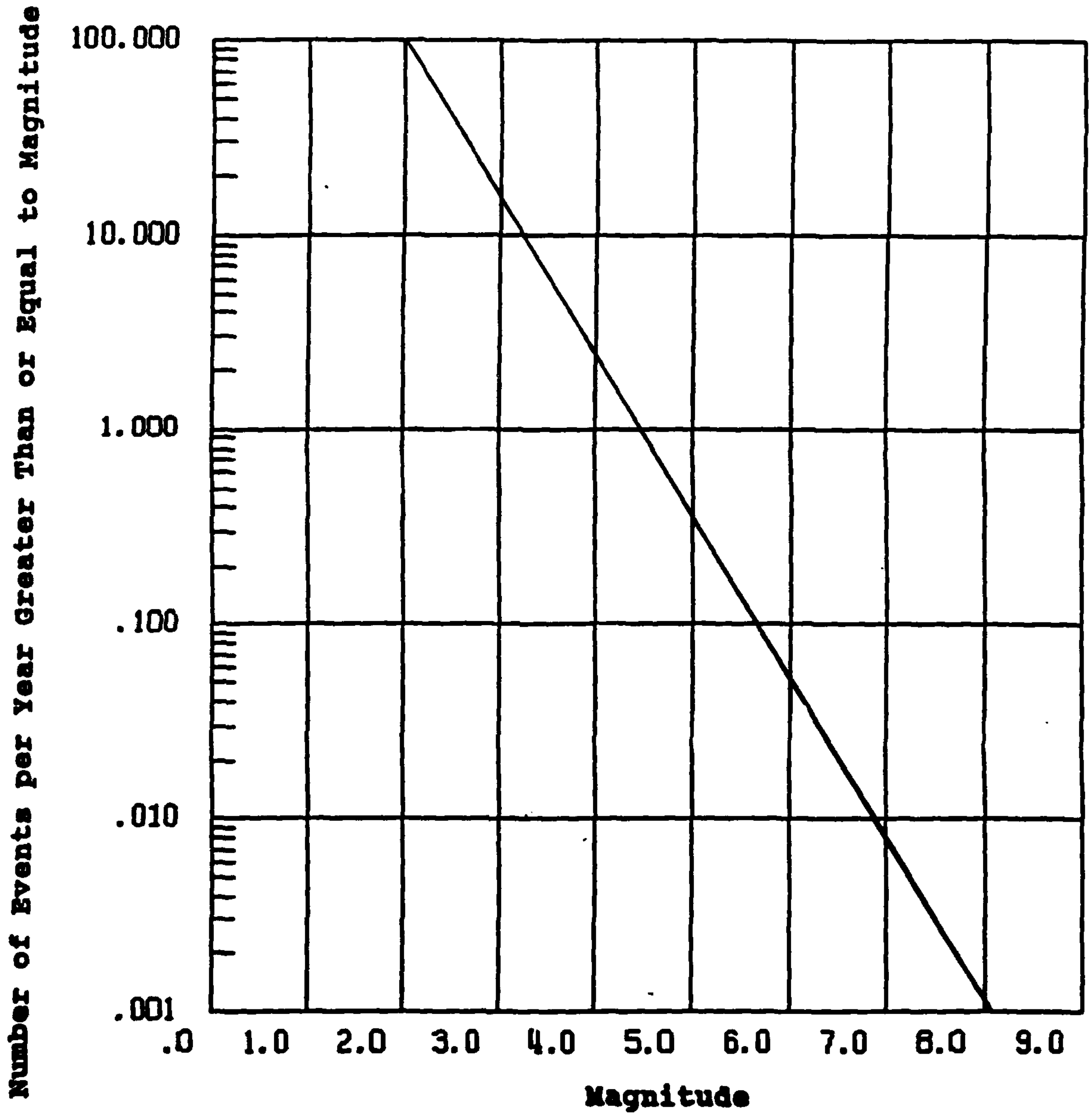
Figure A-64. Fault recurrence.



Fault - UN-NAMED 3 Maximum Magnitude 7

Fault Longitude / Latitude Coordinates
PT1 117.27 , 34.31 PT2 117.14 , 34.44 PT3 116.53 , 34.3

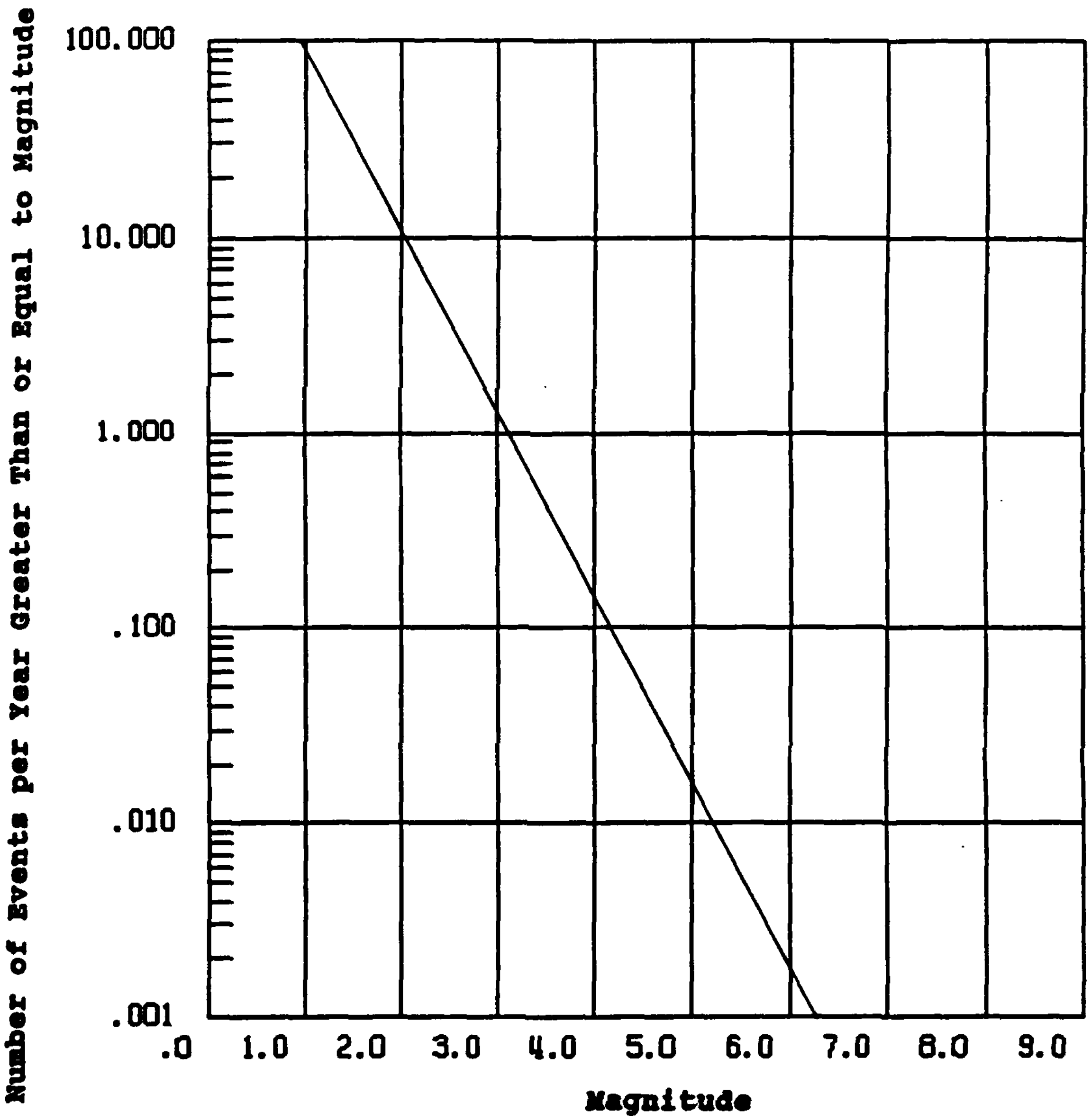
Figure A-65 . Fault recurrence.



Fault - WHITE WOLF   Maximum Magnitude 7.75

Fault Longitude / Latitude Coordinates
PT1 119.02 , 35 PT2 118.76 , 35.16 PT3 118.55 , 35.31

Figure A-66. Fault recurrence.



Fault - WHITTIER

Maximum Magnitude 7.5

Fault Longitude / Latitude Coordinates

PT1 118.03 , 33.98 PT2 117.7 , 33.88 PT3 117.5 , 33.75

Figure A-67 . Fault recurrence.

DISTRIBUTION LIST

NAVFACENGCOM / CO, ALEXANDRIA, VA
NAVFACENGCOM CHESDIV / CO, WASHINGTON, DC
NAVFACENGCOM LANTDIV / CO, NORFOLK, VA
NAVFACENGCOM NORTHDIV / CO, PHILADELPHIA, PA
NAVFACENGCOM PACDIV / CO, PEARL HARBOR, HI
NAVFACENGCOM SOUTHDIV / CO, CHARLESTON, SC
NAVFACENGCOM SOUTHWESTDIV / CO, SAN DIEGO, CA
NAVFACENGCOM WESTDIV / CO, SAN BRUNO, CA
PWC / PENSACOLA, FL
PWC / GREAT LAKES, IL
PWC / CO, PEARL HARBOR, HI
PWC / CO, FPO AP
PWC / CO, SAN DIEGO, CA
PWC / CO, OAKLAND, CA
PWC / CO, FPO AP
PWC / PHILIPPINES, FPO AP
PWC / YOKOSUKA, FPO AP